

Automating Electricity Access Prediction Using Satellite Imagery

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Bass Connections Energy Data Analytics Lab • April 2018



People gather for town meeting around tractor lights.
Yet Fateh Naglah is categorized as being electrified by Indian government

Source: Bloomberg



Bloomberg

Living in the Dark: 240 Million Indians Have No Electricity

50 million rural homes without power despite idle generation.

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THE HINDU

All villages in Bihar electrified, says Nitish Kumar



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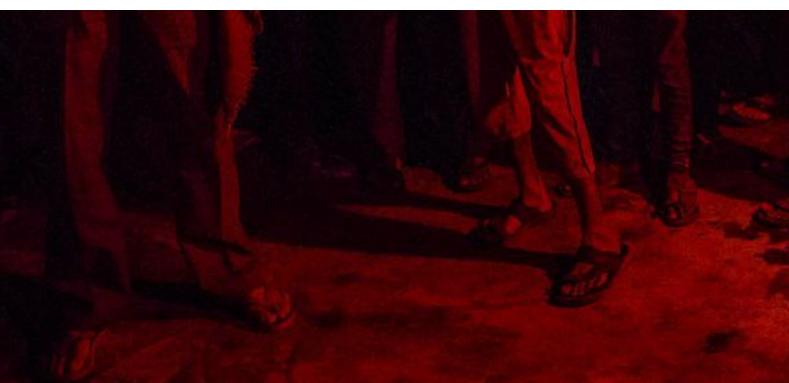
Bloomberg

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All villages in Bihar electrified, says Nitish Kumar



hindustantimes

In 2 years, BJP govt electrified 13523 villages; only 8% were completely electrified

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Forbes

Power To The People: India Plans To Electrify 40 Million Households By 2018

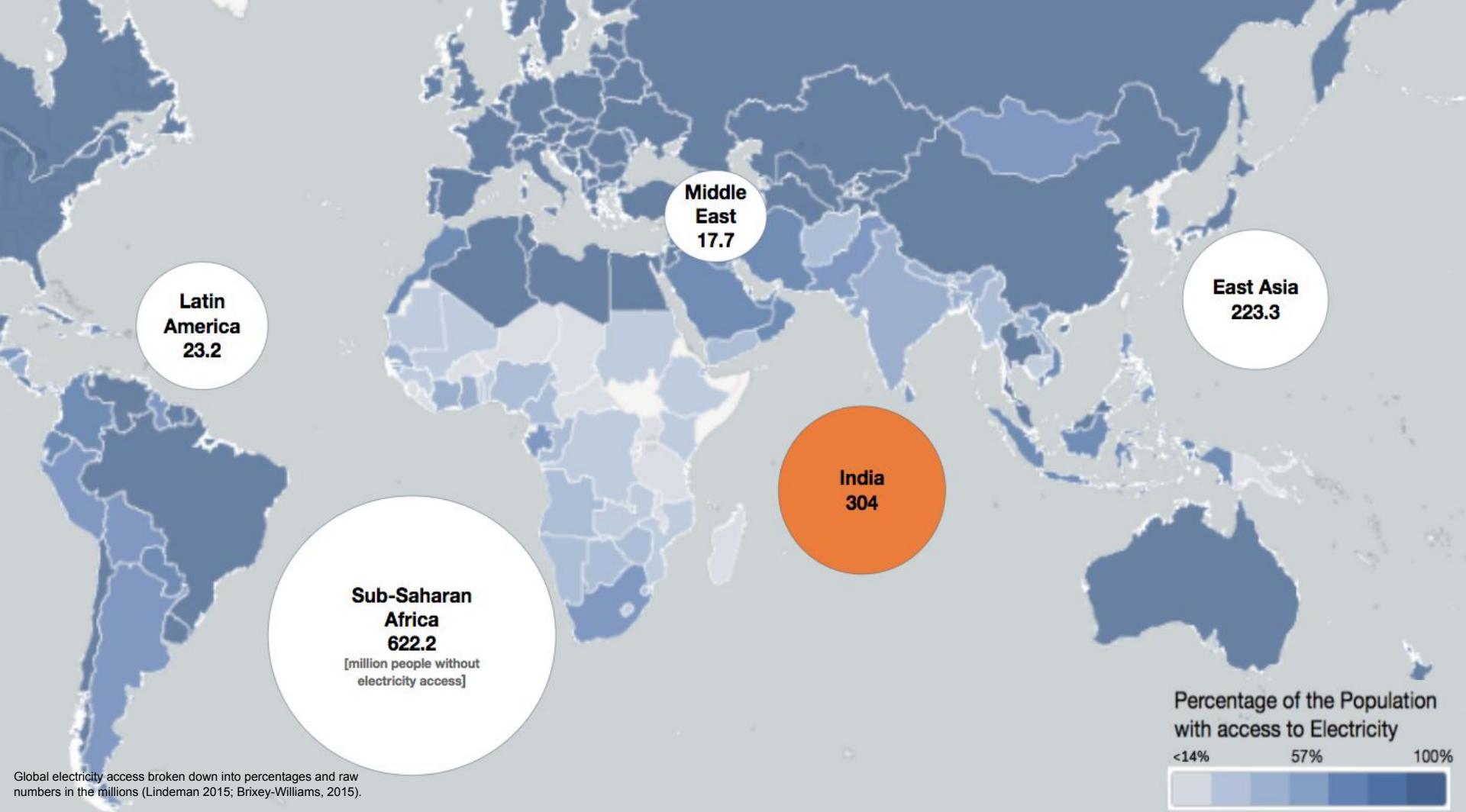


hindustantimes

In 2 years, BJP govt electrified 13523 villages; only 8% were completely electrified

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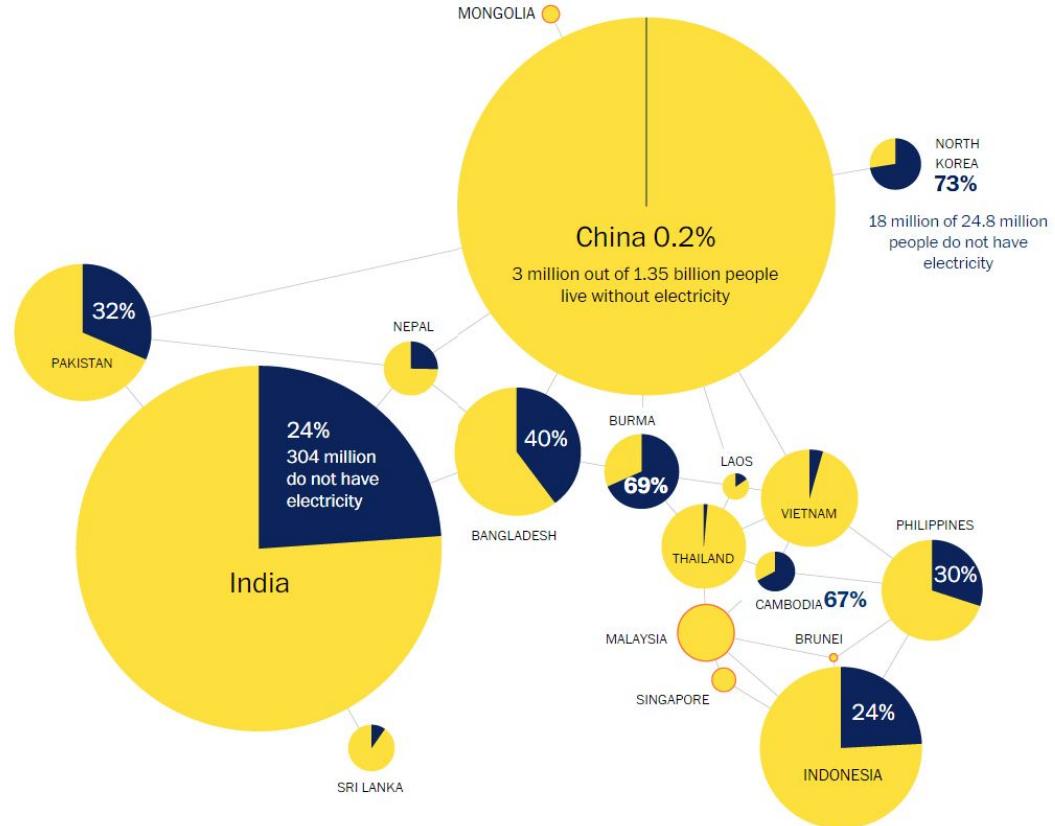
India's Significance

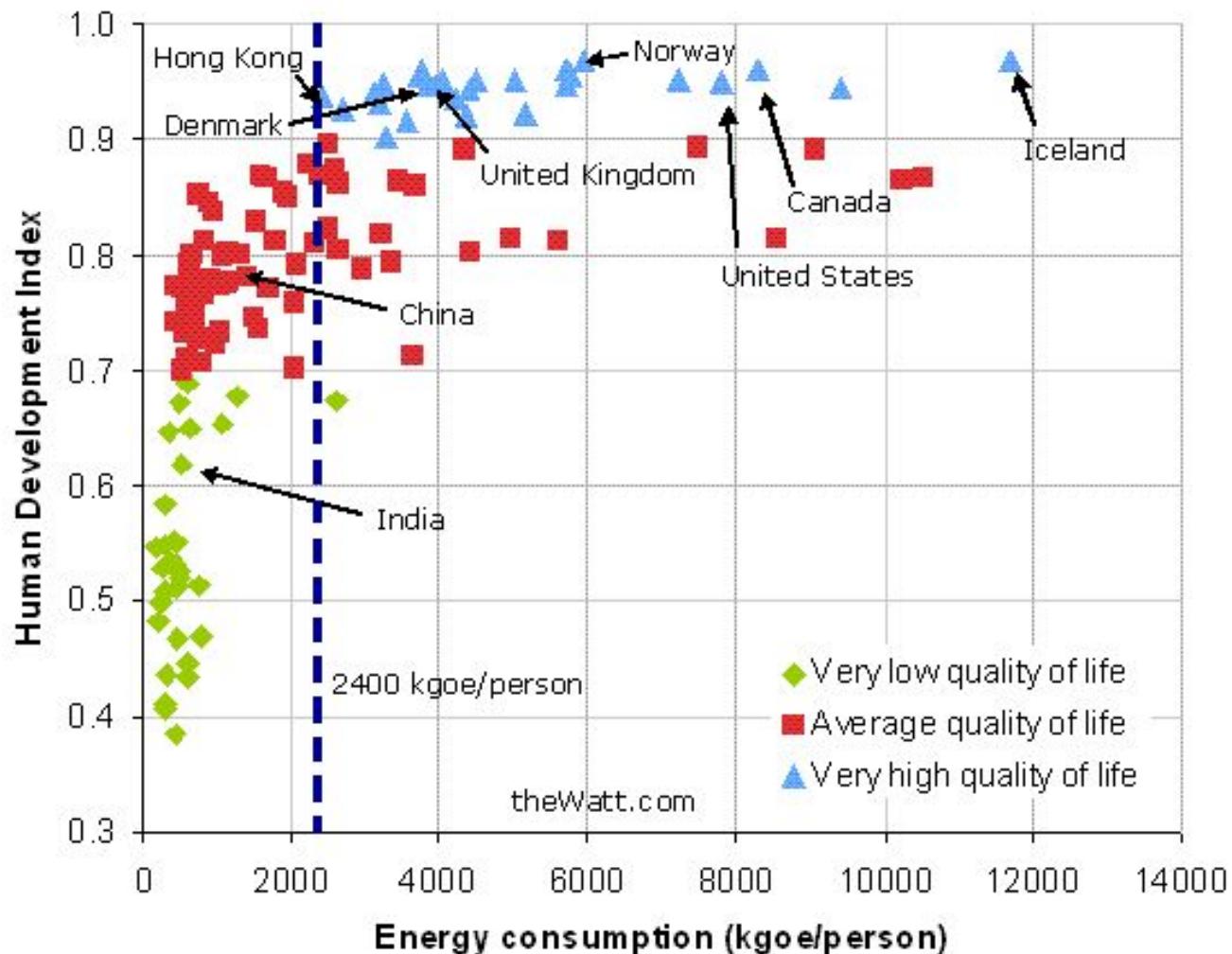
304 million people
without electricity
access

Government data
provides **village level**
electrification rates

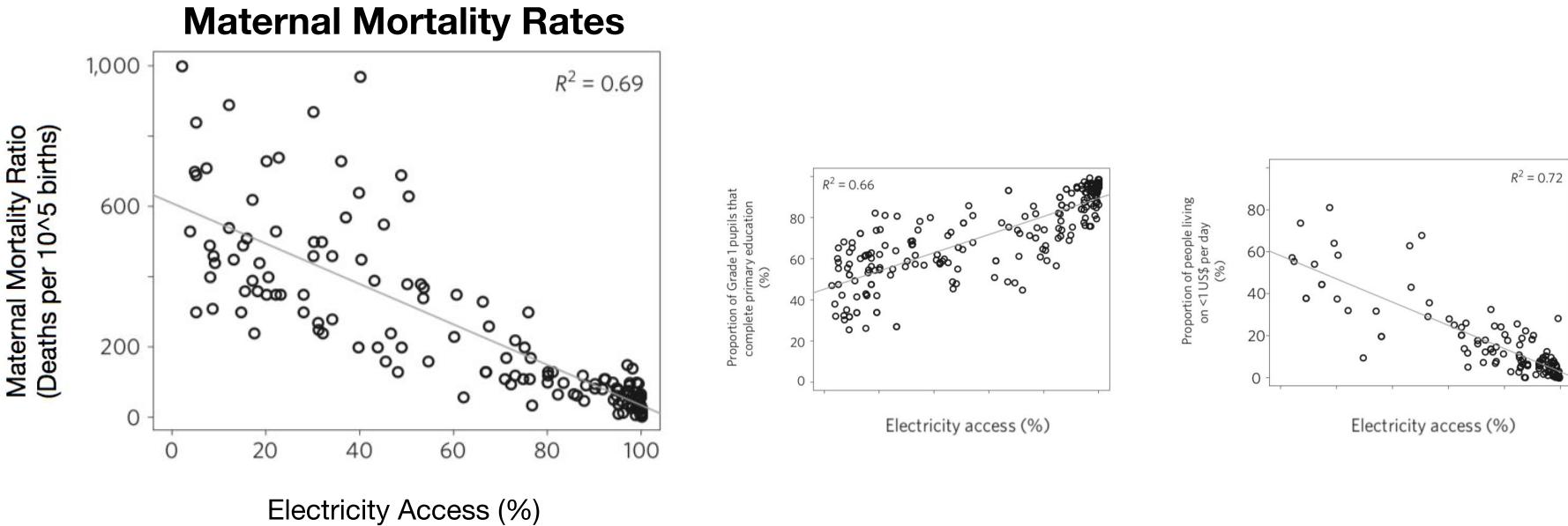
Narendra Modi's
\$2.5B plan to bring
100% access

622 million
of 3.6 billion people do
not have electricity

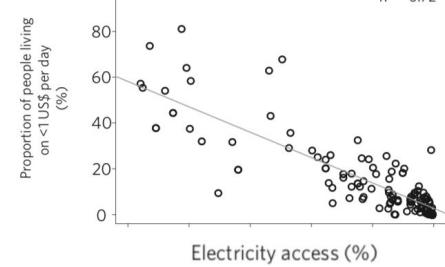
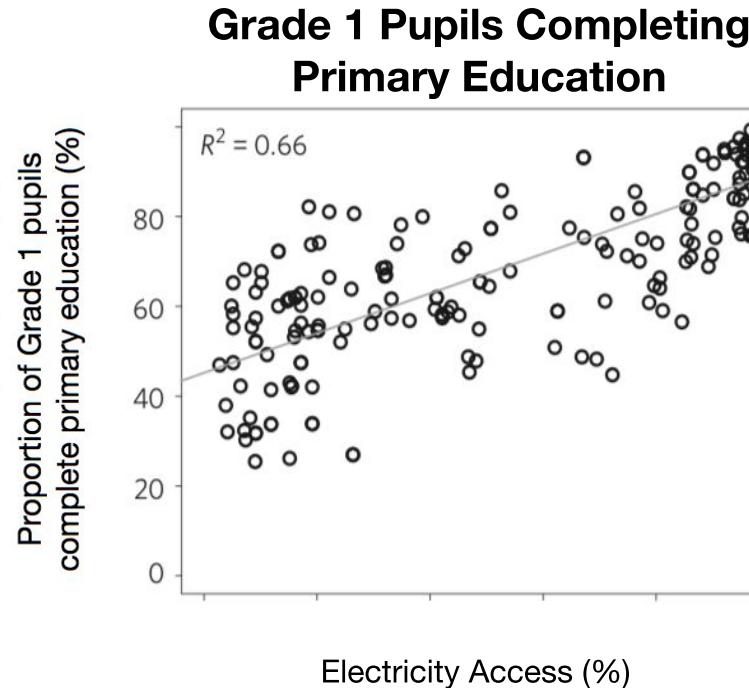
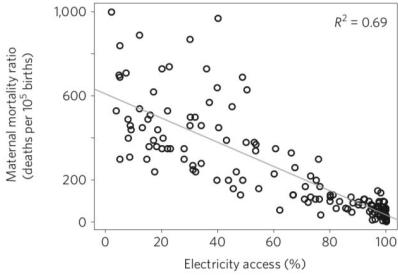




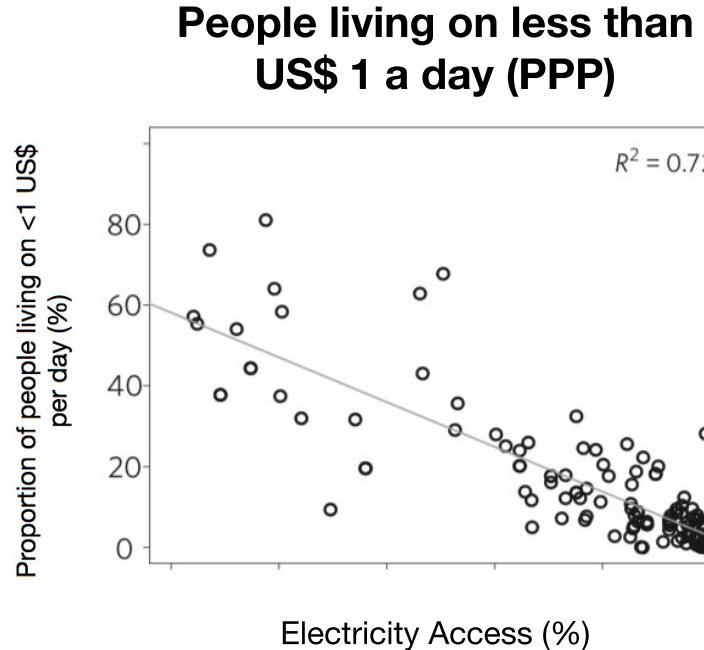
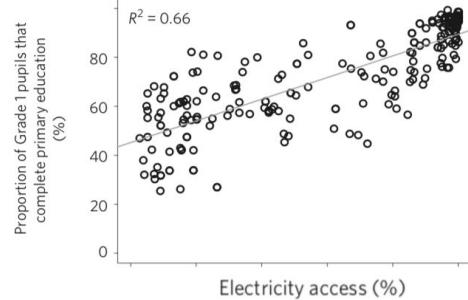
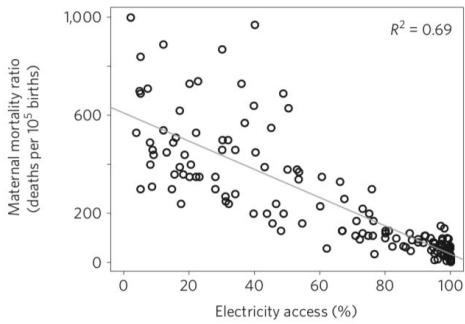
Benefits of Electricity Access



Benefits of Electricity Access



Benefits of Electricity Access



Data Scale Matters

Araria District, Bihar

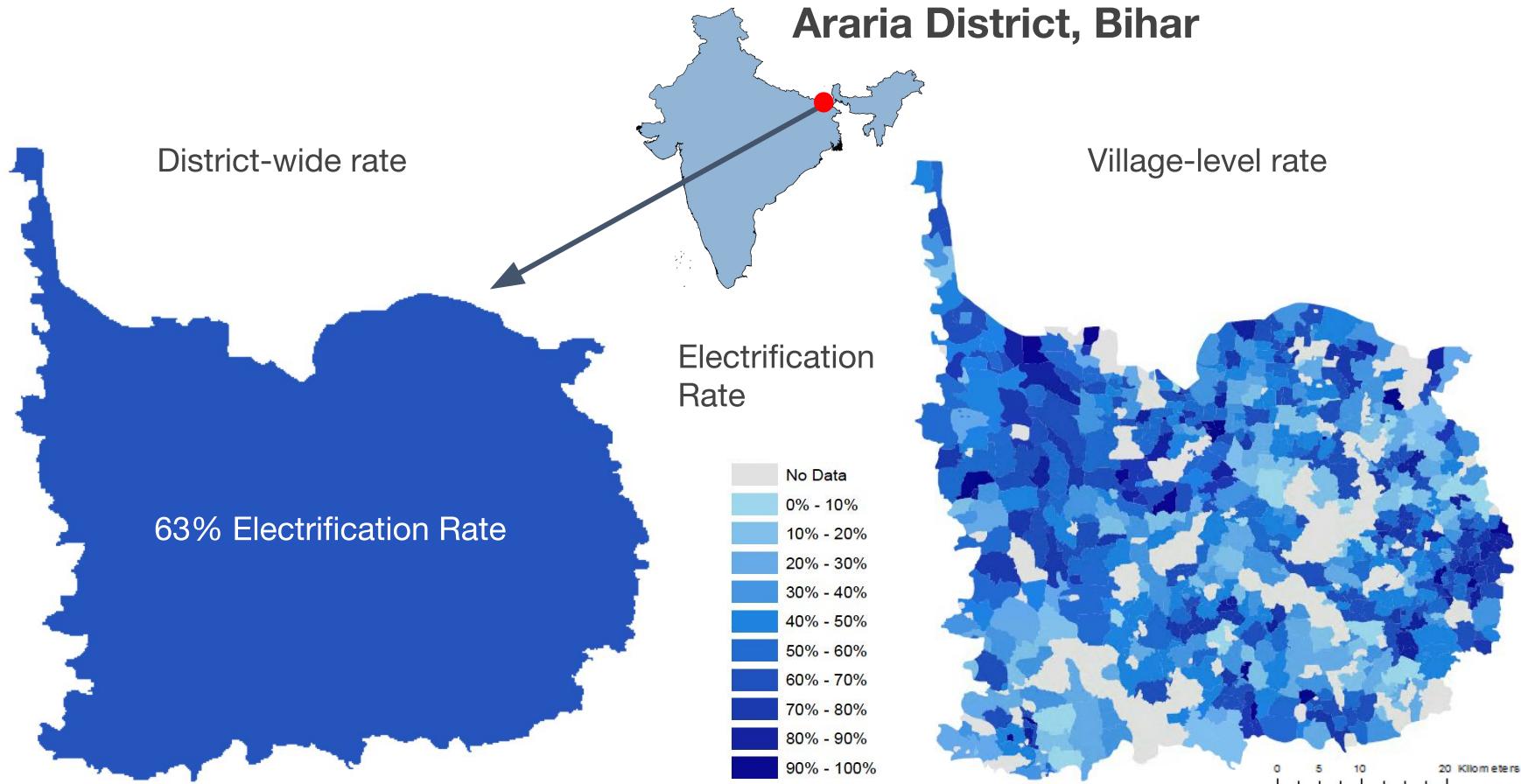


Data Scale Matters

Araria District, Bihar

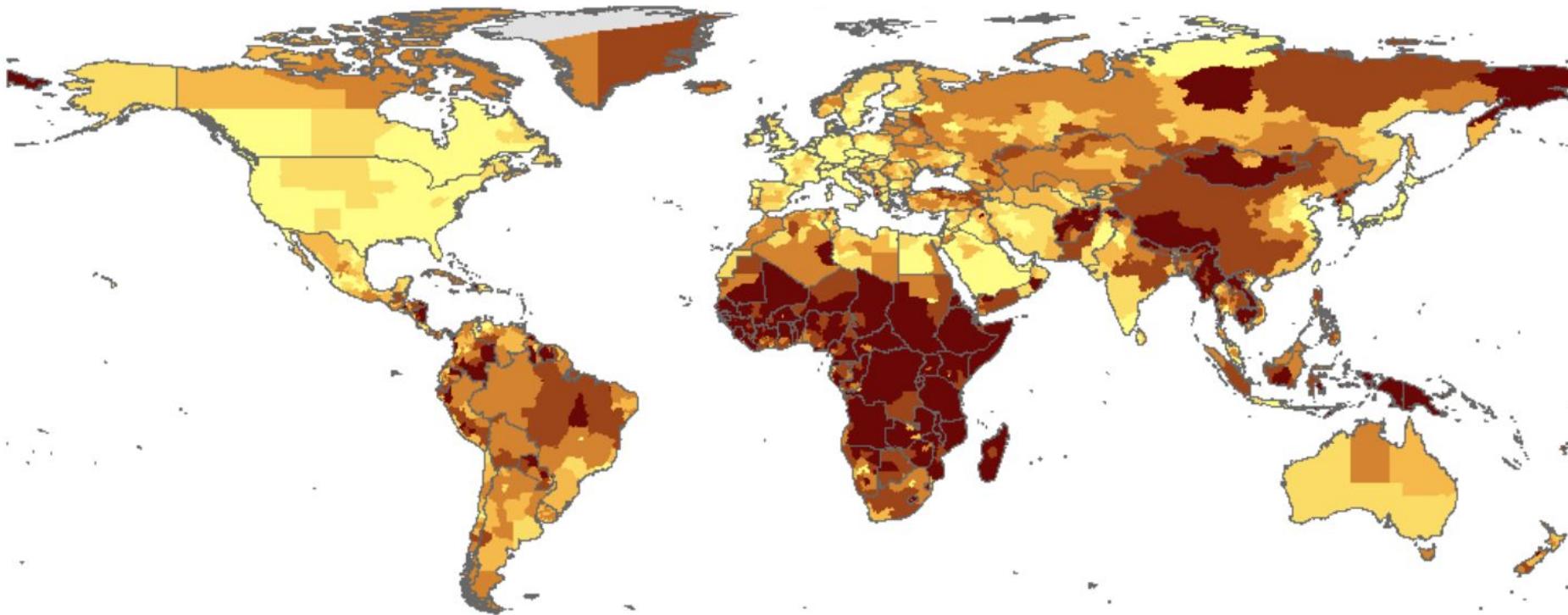


Data Scale Matters



Who's in the Dark: Satellite Based Estimates of Electrification Rates

Christopher D. Elvidge, Earth Observation Group, NOAA National Geophysical Data Center



Legend

0 - 30

30 - 60

60 - 80

80 - 90

90 - 96

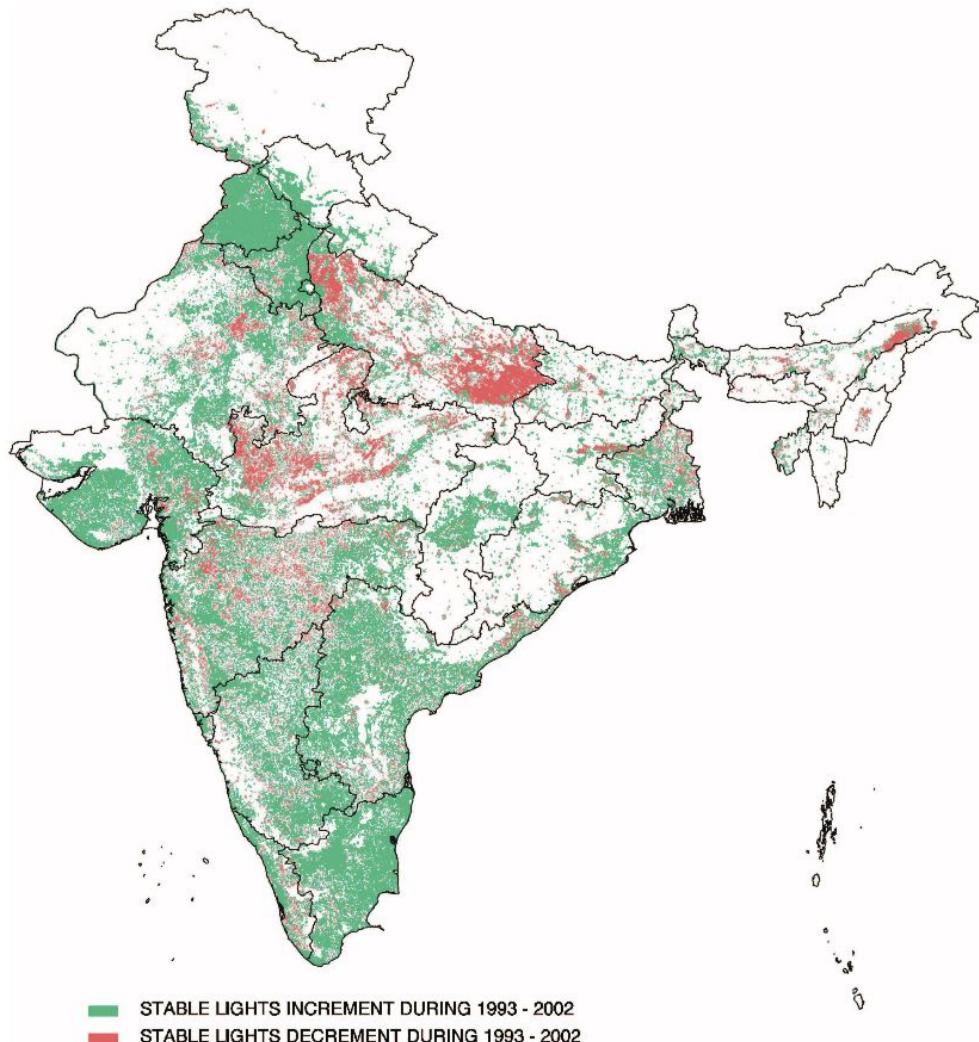
96 - 100

No Data

State-level electrification rates based on lights at night data

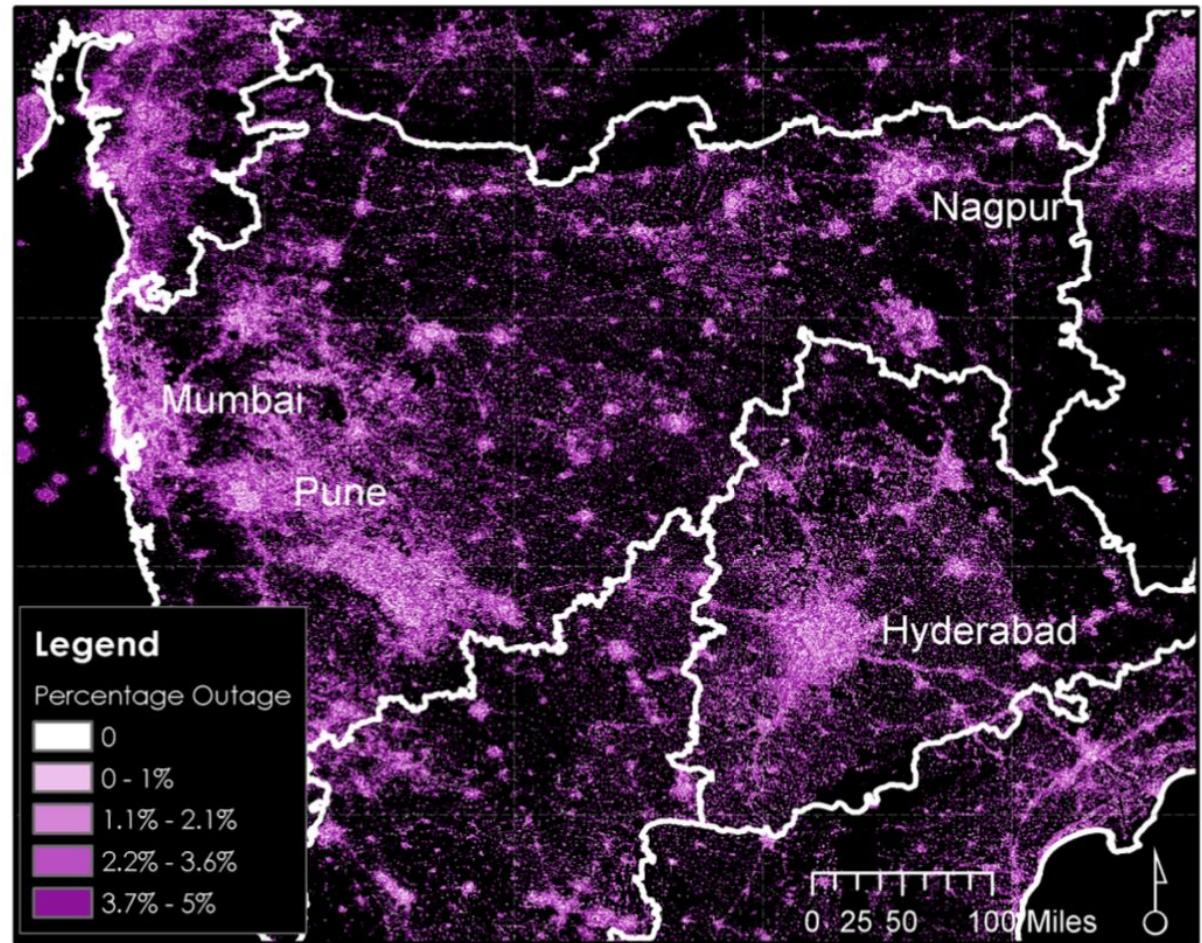
Spatial characterization of electrical power consumption patterns over India using temporal DMSP-OLS night-time satellite data

T. R. Kiran Chand, National Remote Sensing Agency,
Department of Space, Government of India



Using VIIRS Day/Night Band to Measure Electricity Supply Reliability: Preliminary Results from Maharashtra, India

Michael L. Mann, The Department of Geography, George Washington University



The Goal

Build an **automated** and **scalable** mechanism for predicting **high resolution electrification rates** using satellite imagery and machine learning

Traditional Approach



Source: Mulnivasi Organiser

Sporadic
Low granularity
Expensive
Limited data in remote regions

Traditional Approach



Source: Mulnivasi Organiser

Sporadic
Low granularity
Expensive
Limited data in remote regions

Our Approach



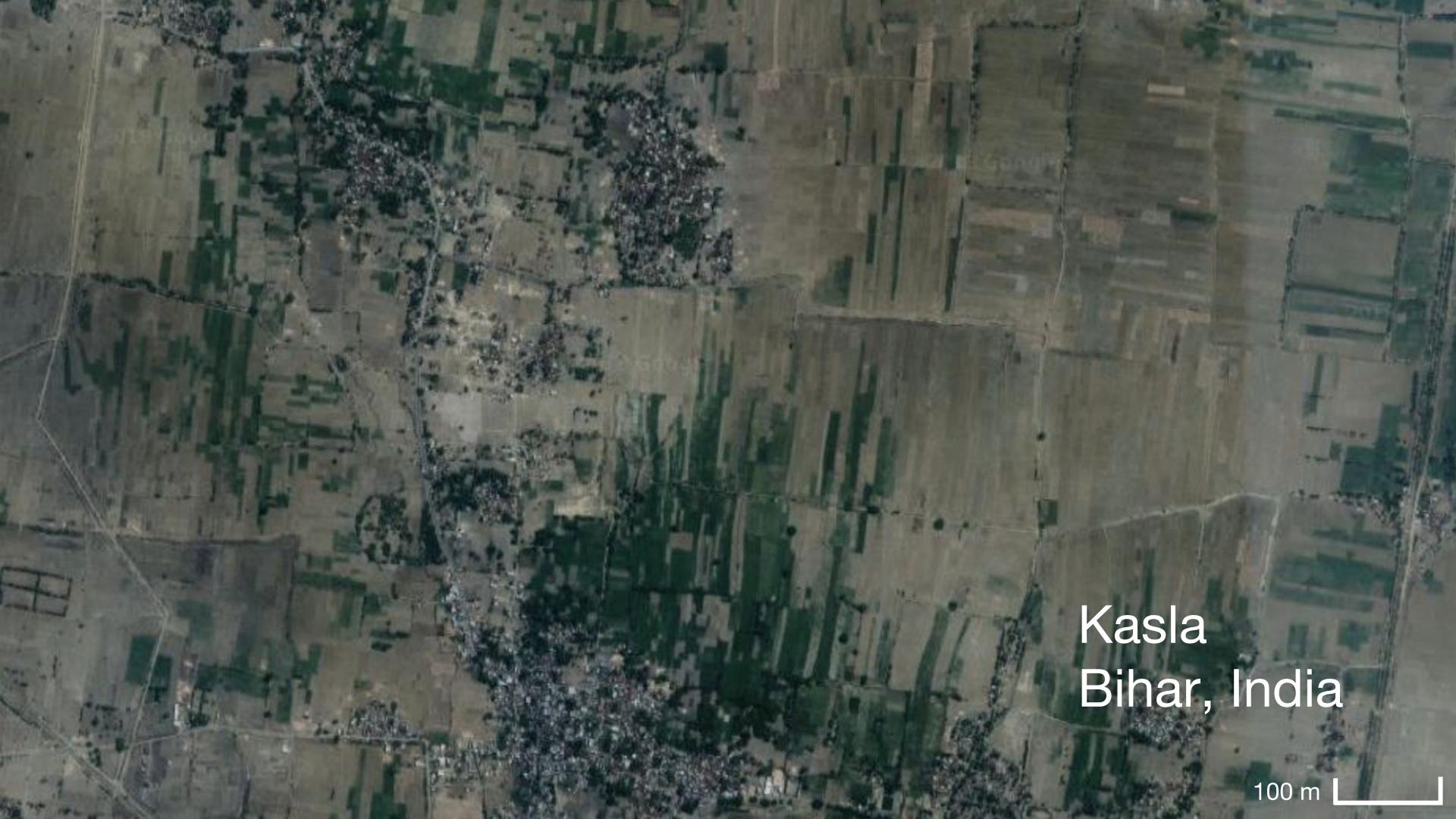
Source: NASA

Regular
Automated
Cost-effective
High resolution
Global coverage

An aerial satellite photograph showing a large area of agricultural land. The fields are organized into a grid-like pattern, with varying shades of brown and green indicating different crops or soil types. A small town or cluster of buildings is visible in the lower-left portion of the image, surrounded by fields. The overall scene is a rural landscape.

What can we infer from an image?

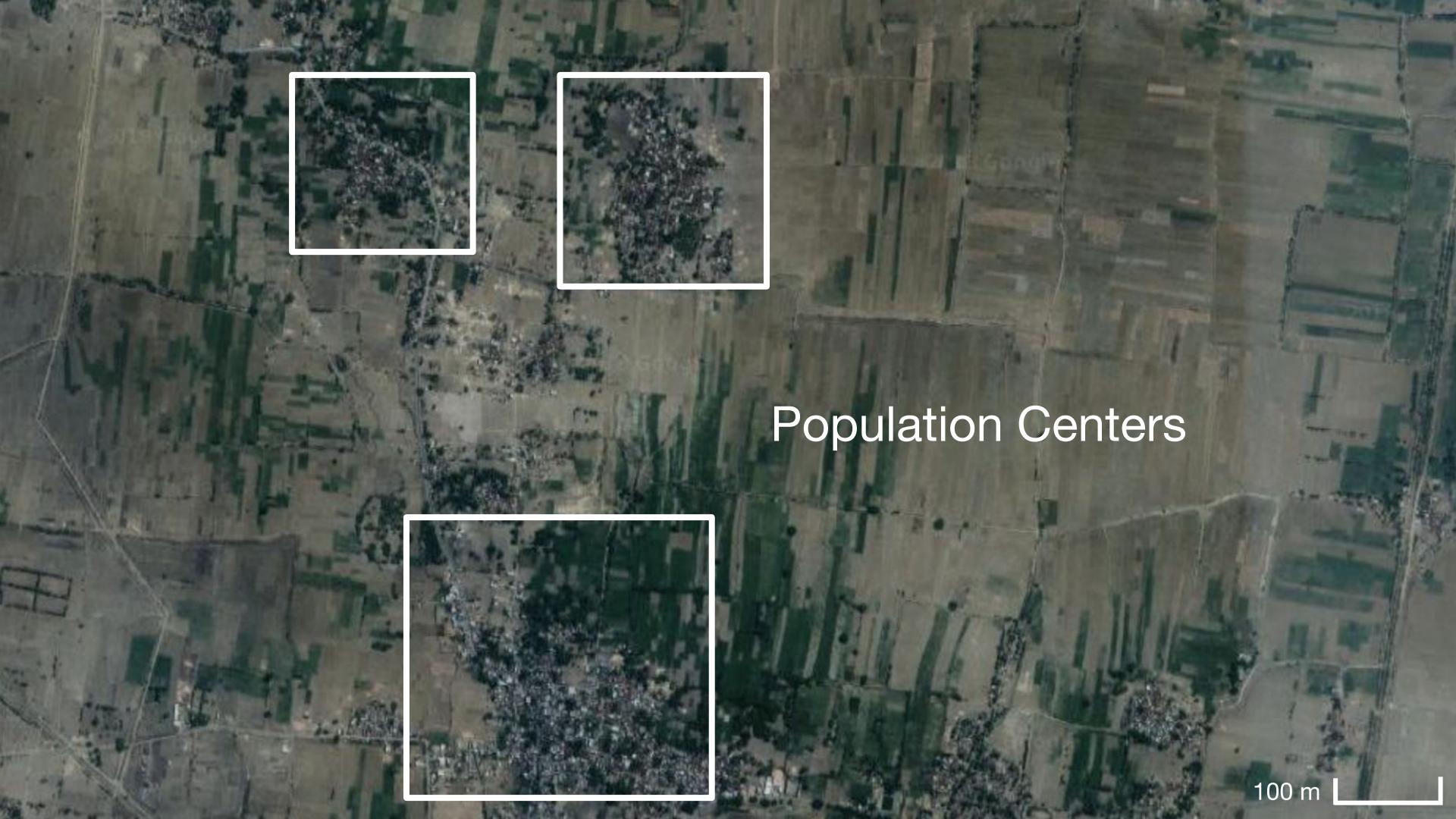
100 m



A satellite map of a rural area in Bihar, India. The landscape is characterized by a patchwork of agricultural fields in shades of brown, green, and tan, separated by a network of roads and irrigation canals. Small clusters of buildings, likely villages, are scattered throughout the fields. The overall pattern is one of organized agriculture on a large scale.

Kasla
Bihar, India

100 m



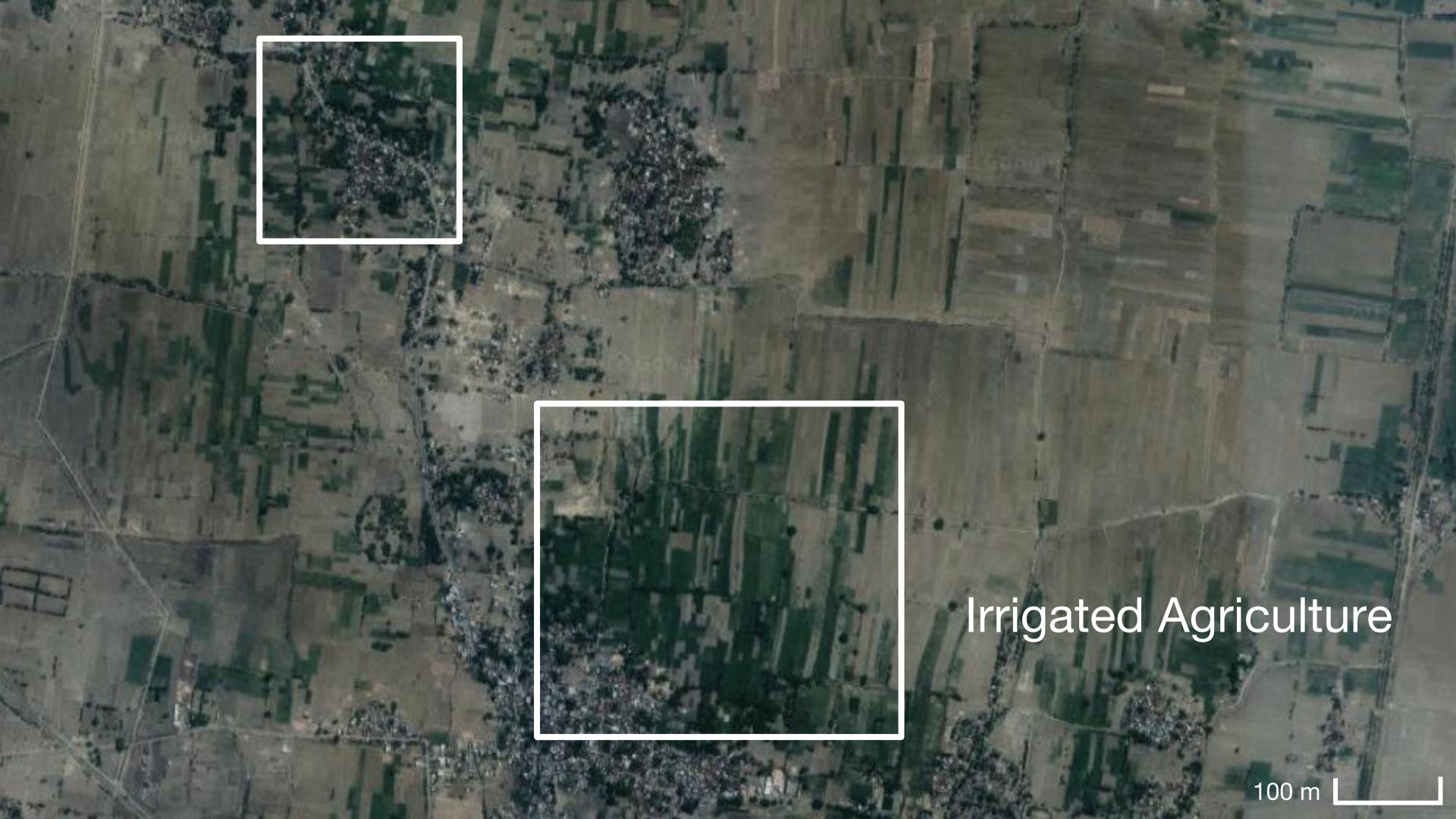
Aerial satellite map showing agricultural fields and population centers. The map displays a patchwork of green and brown fields, likely rice paddies and dry land crops, separated by a network of roads and canals. Three specific areas are highlighted with white boxes:

- Top Left Box: A cluster of buildings and trees, indicating a population center.
- Top Right Box: Another cluster of buildings and trees, indicating a population center.
- Bottom Box: A larger cluster of buildings and trees, indicating a population center.

The text "Population Centers" is overlaid on the map, positioned between the top two highlighted areas.

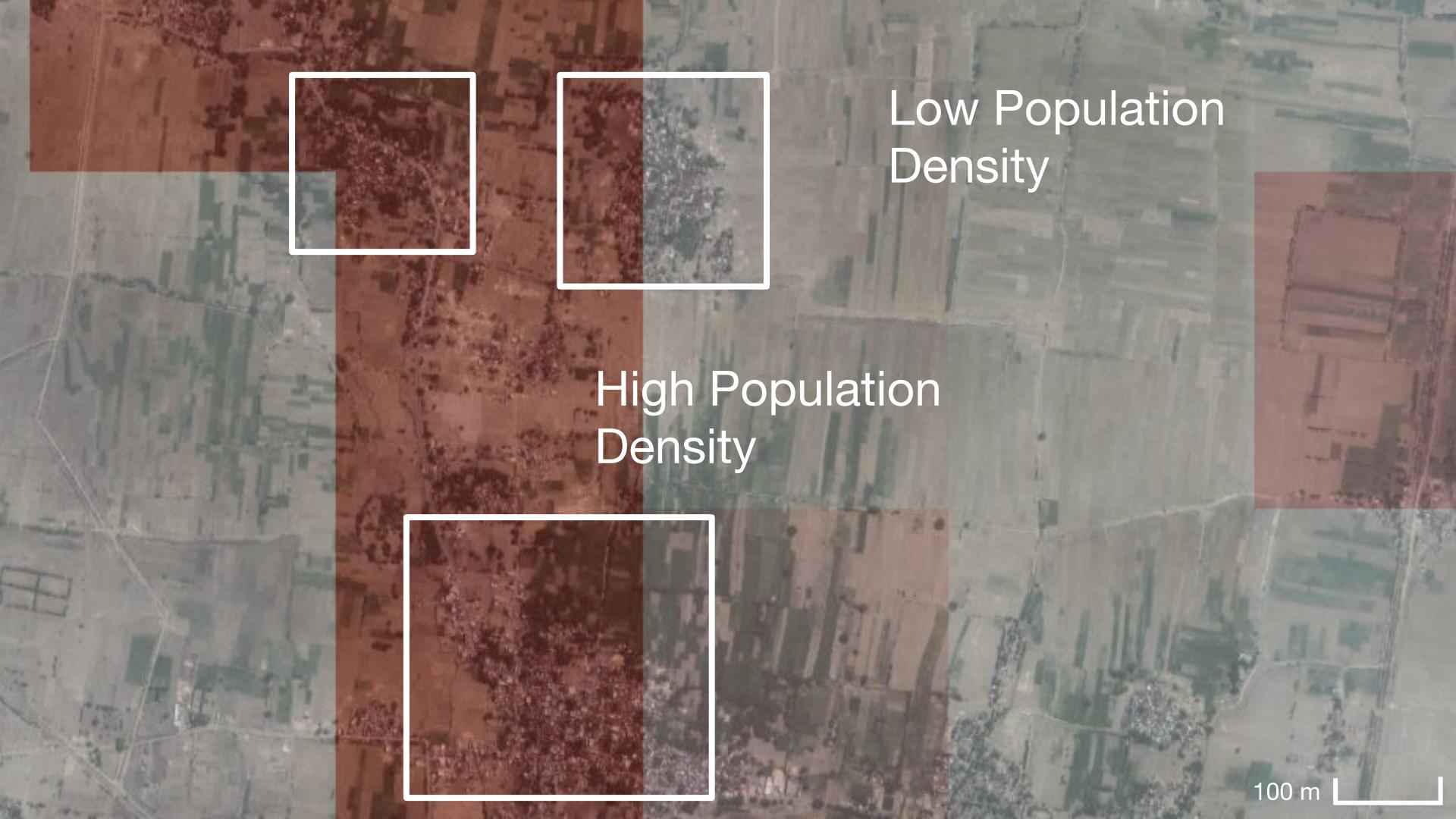
Population Centers

100 m



Irrigated Agriculture

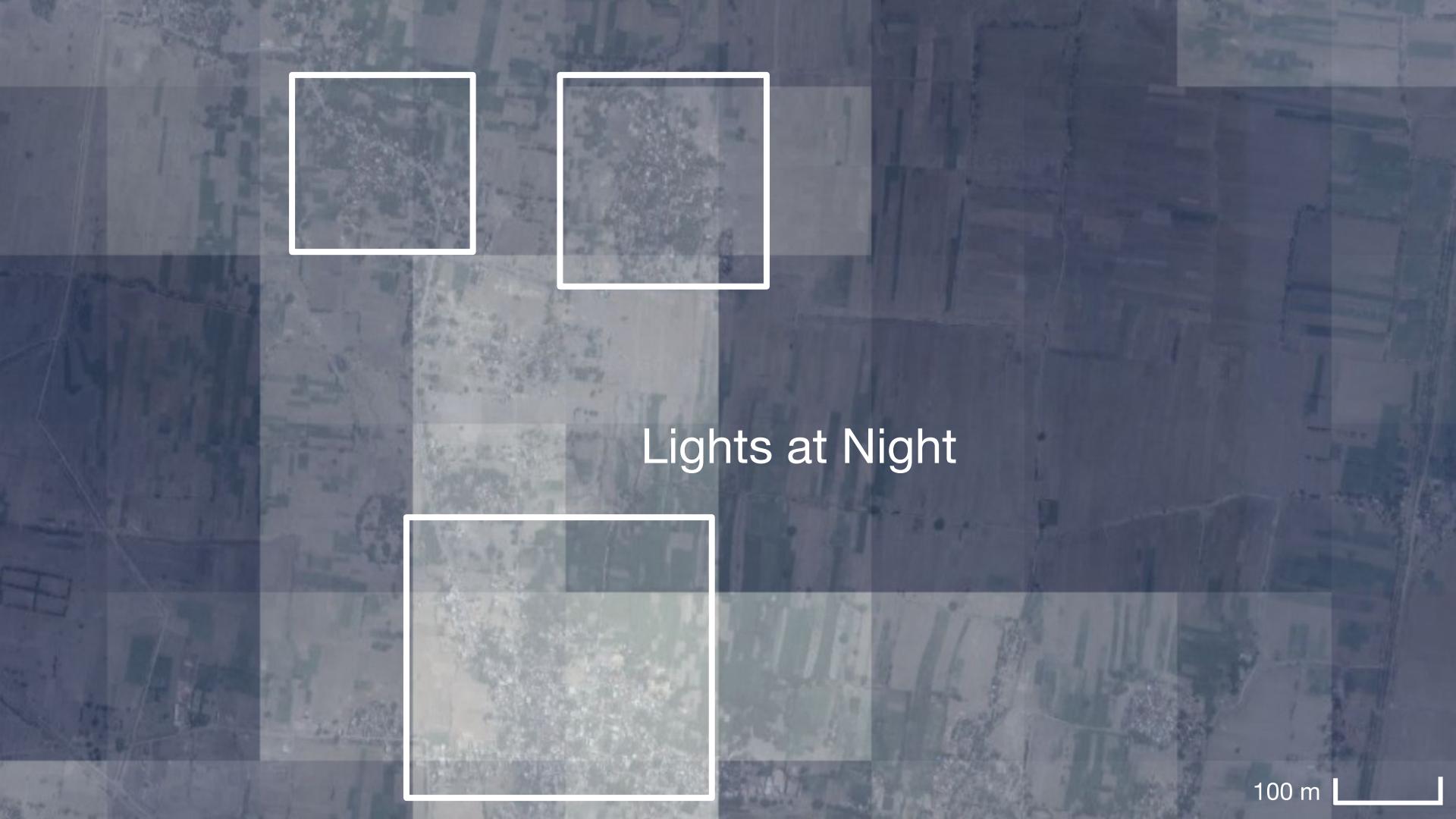
100 m



Low Population
Density

High Population
Density

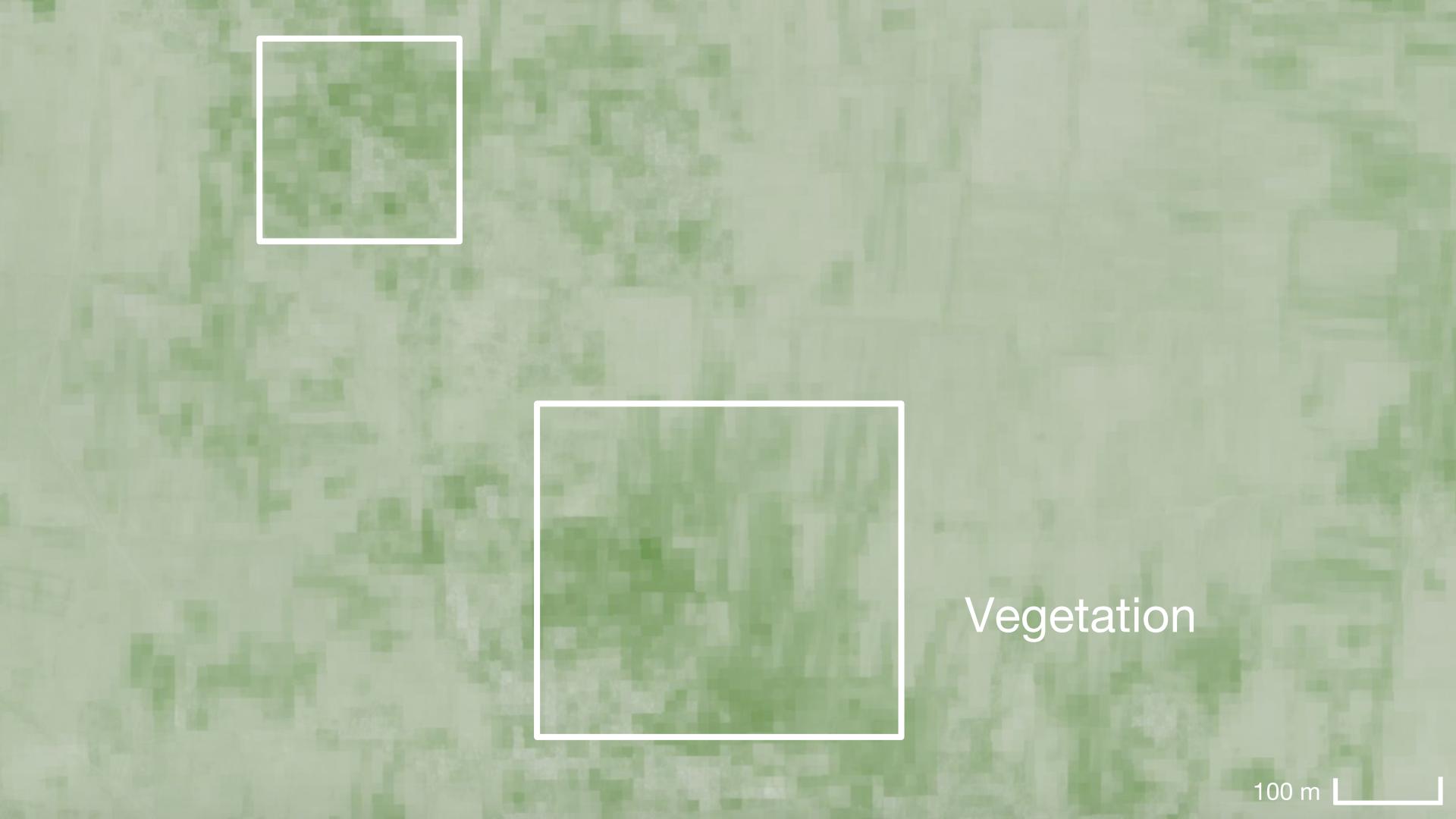
100 m



Lights at Night

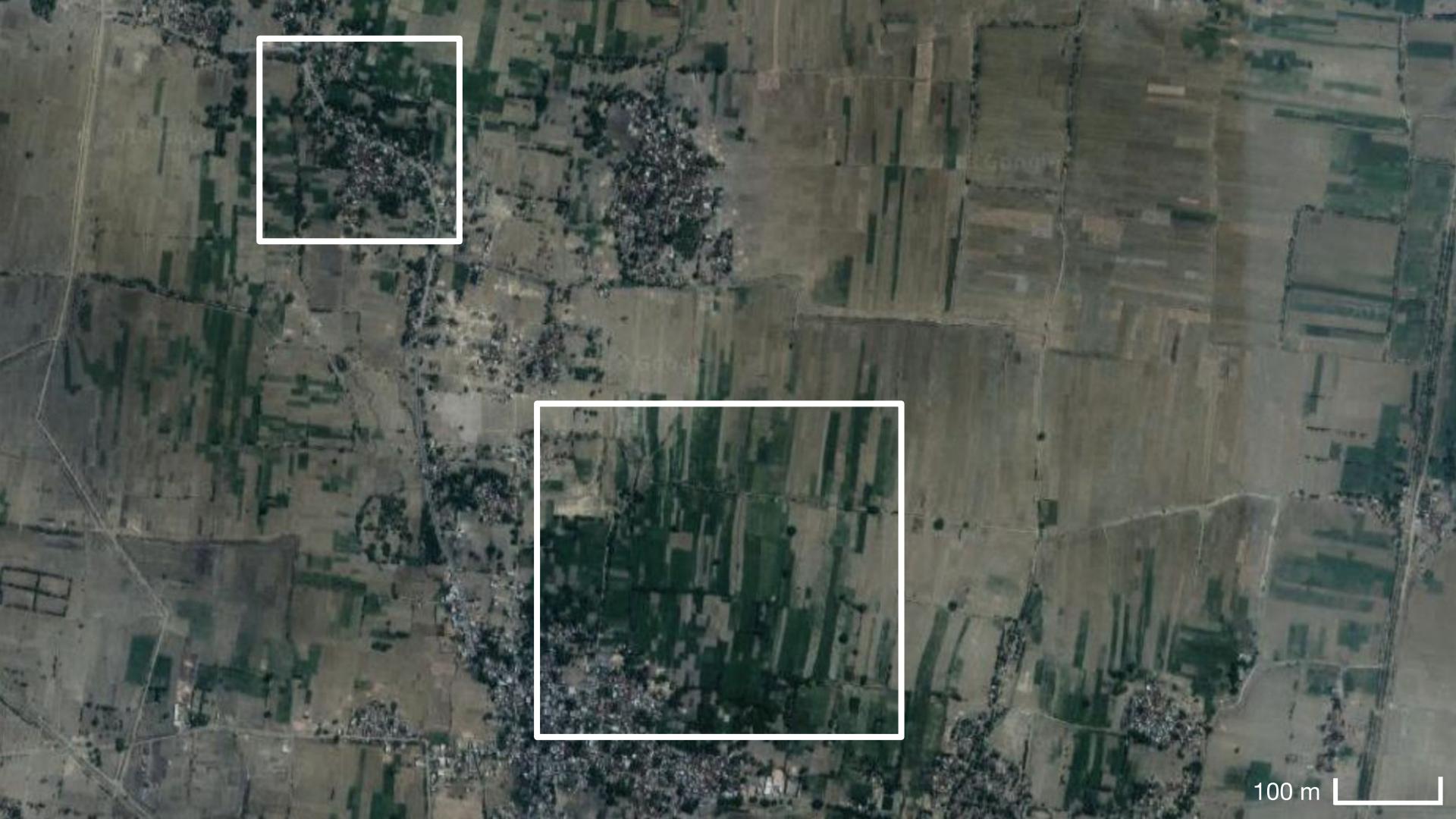
This image is a composite of aerial satellite imagery showing agricultural fields and a small town. The town is visible as a cluster of buildings with lights on at night. Three specific areas are highlighted with white rectangles: one in the upper left, one in the upper right, and one in the lower center. A scale bar in the bottom right corner indicates a distance of 100 meters.

100 m

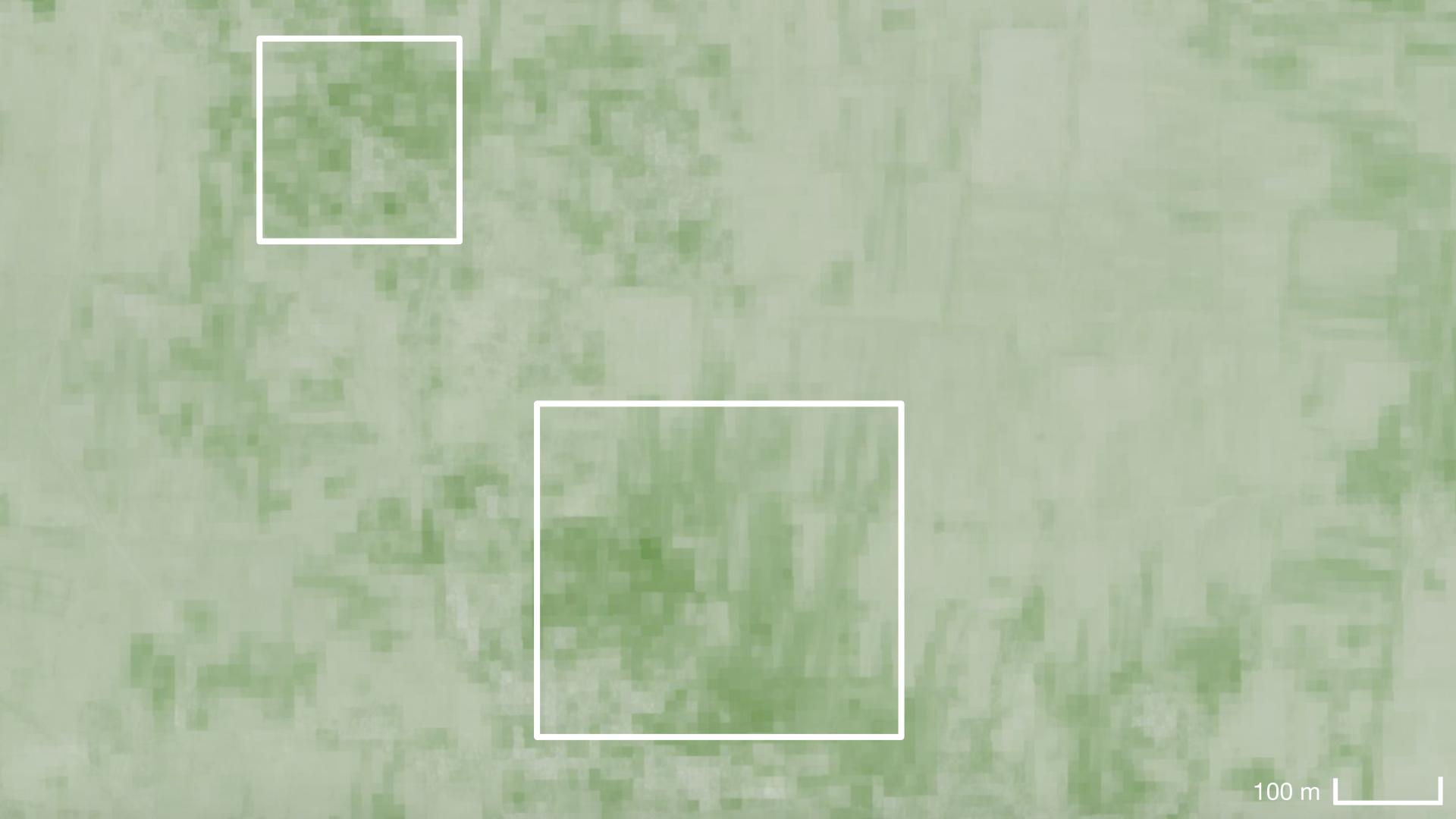


Vegetation

100 m

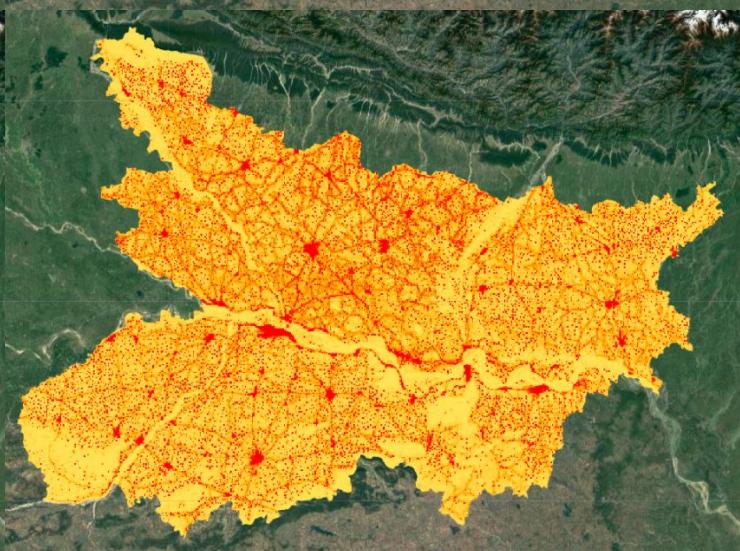
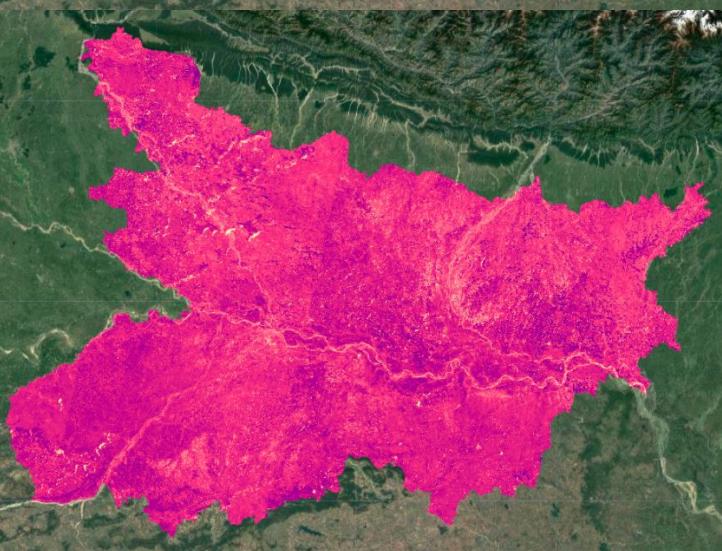
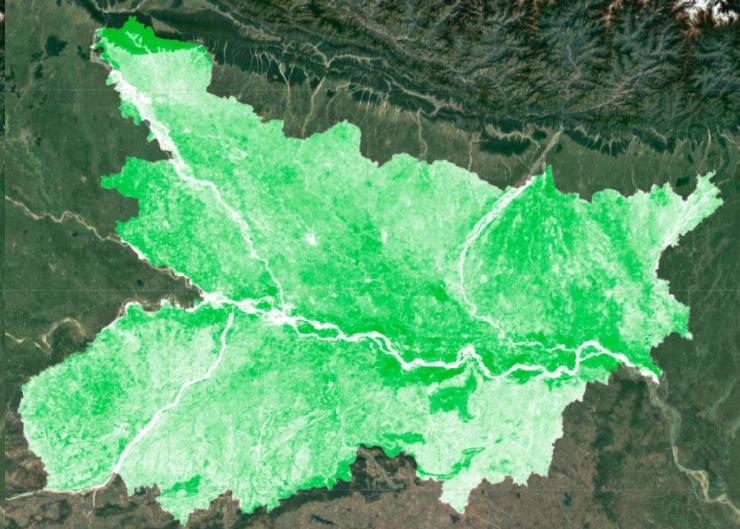


100 m

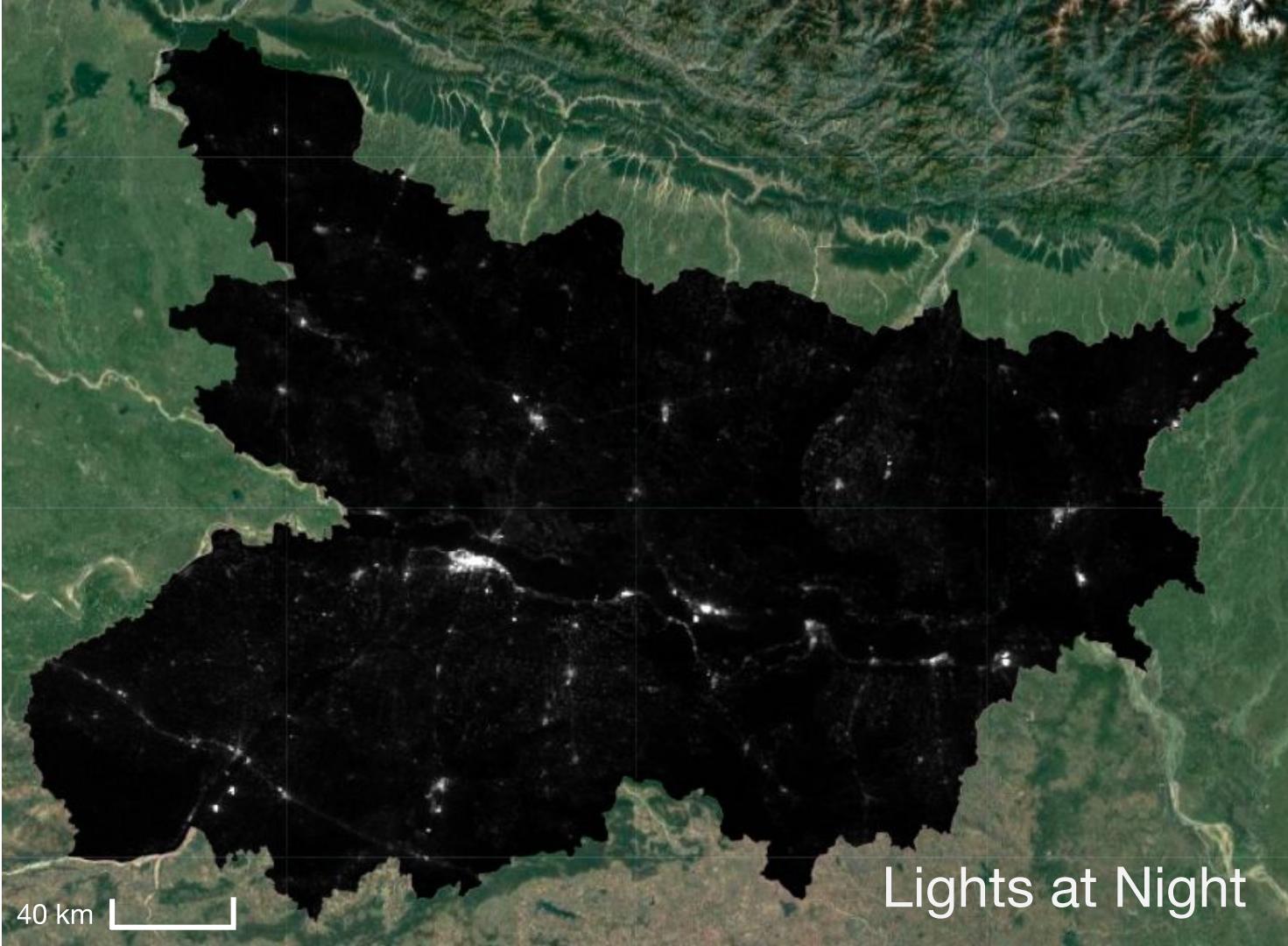
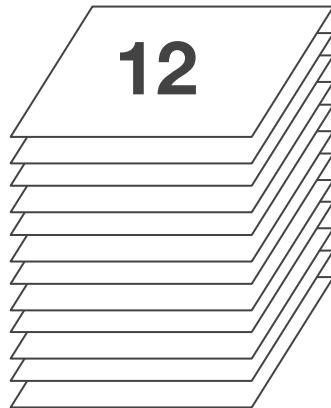


100 m

The Data

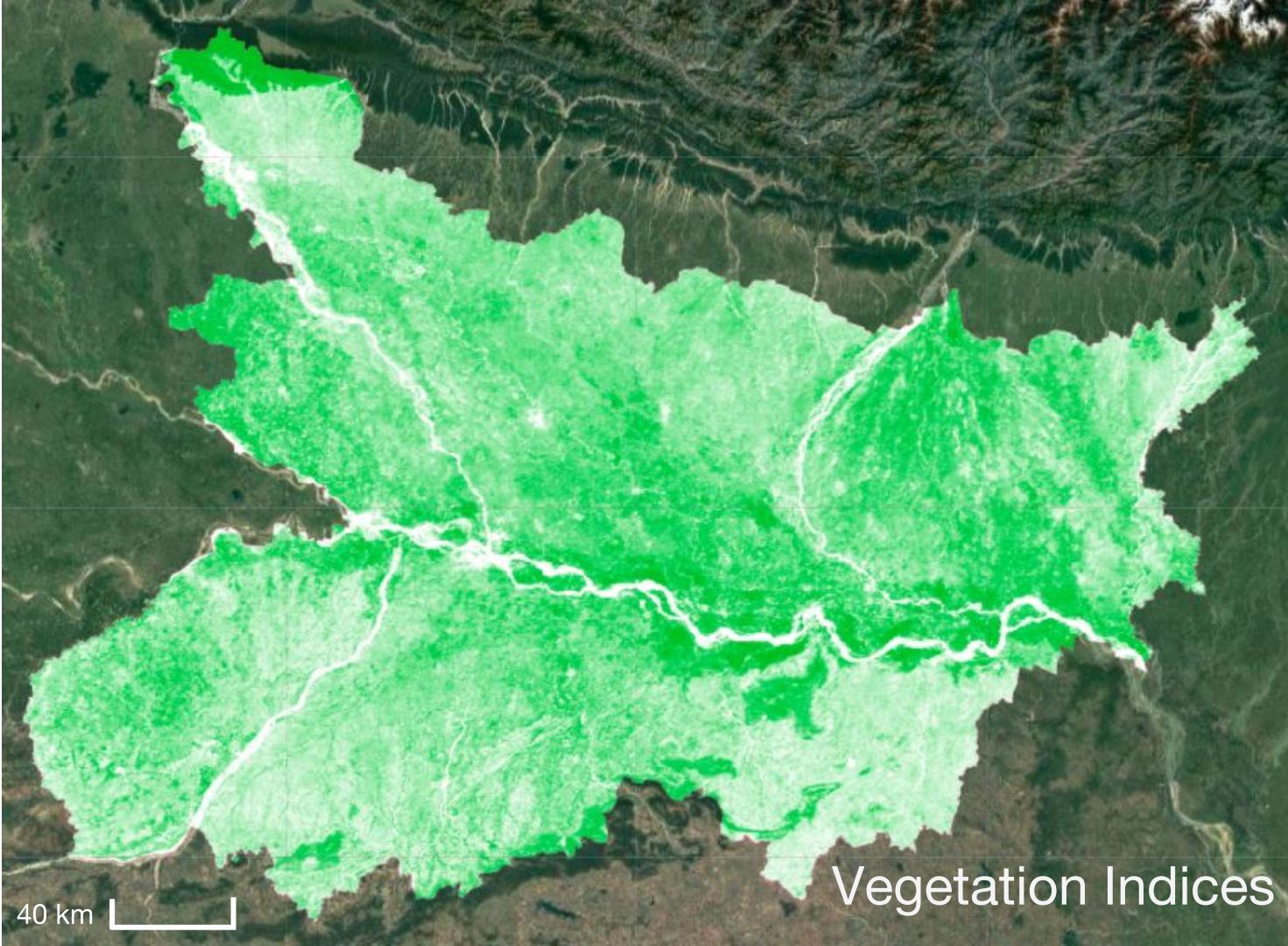


The Data



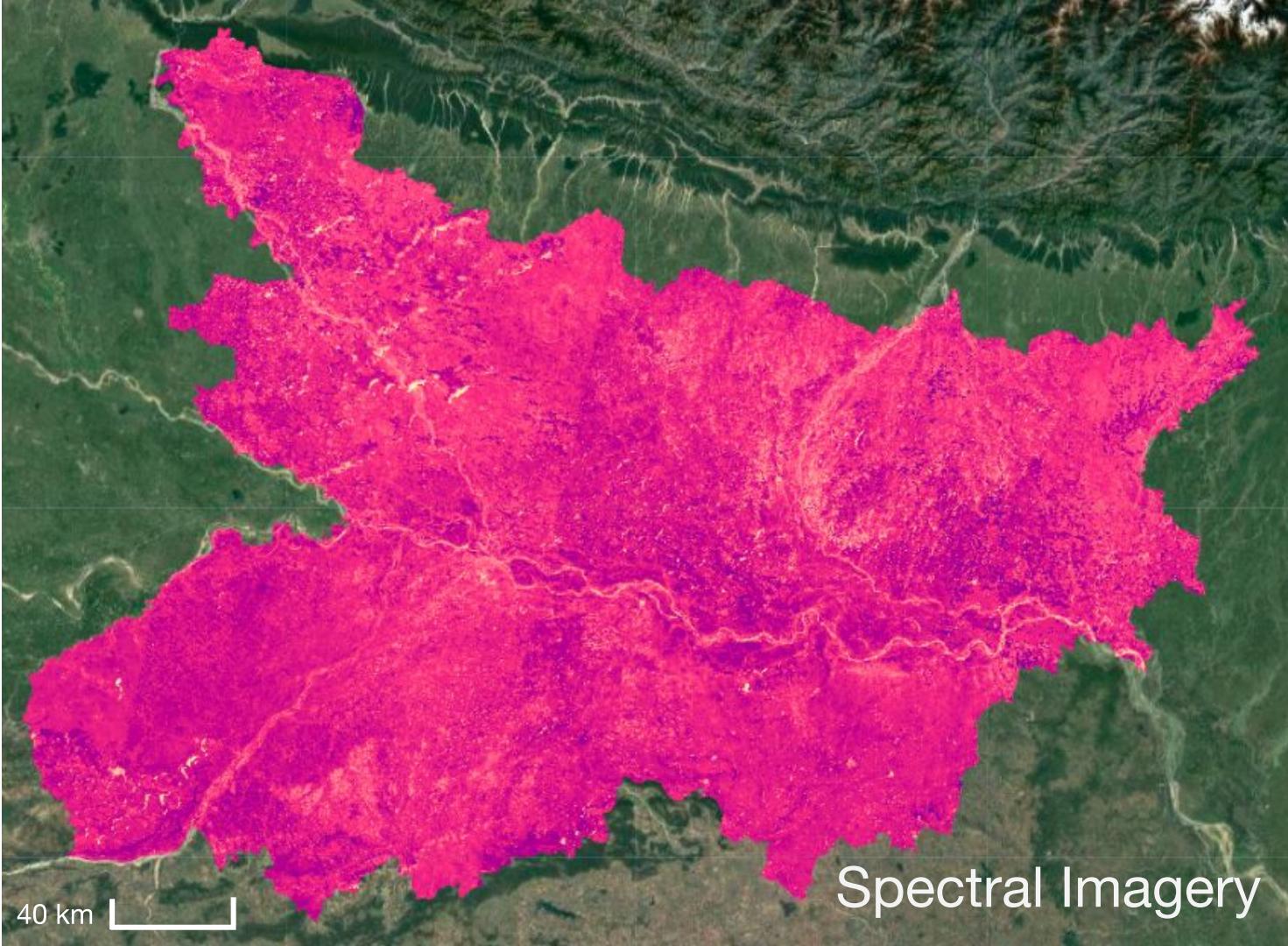
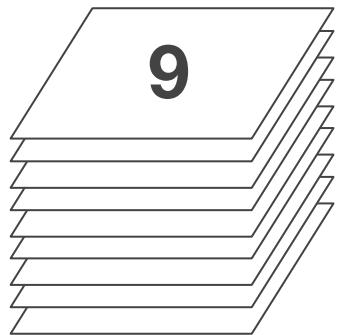
The Data

24



40 km

The Data

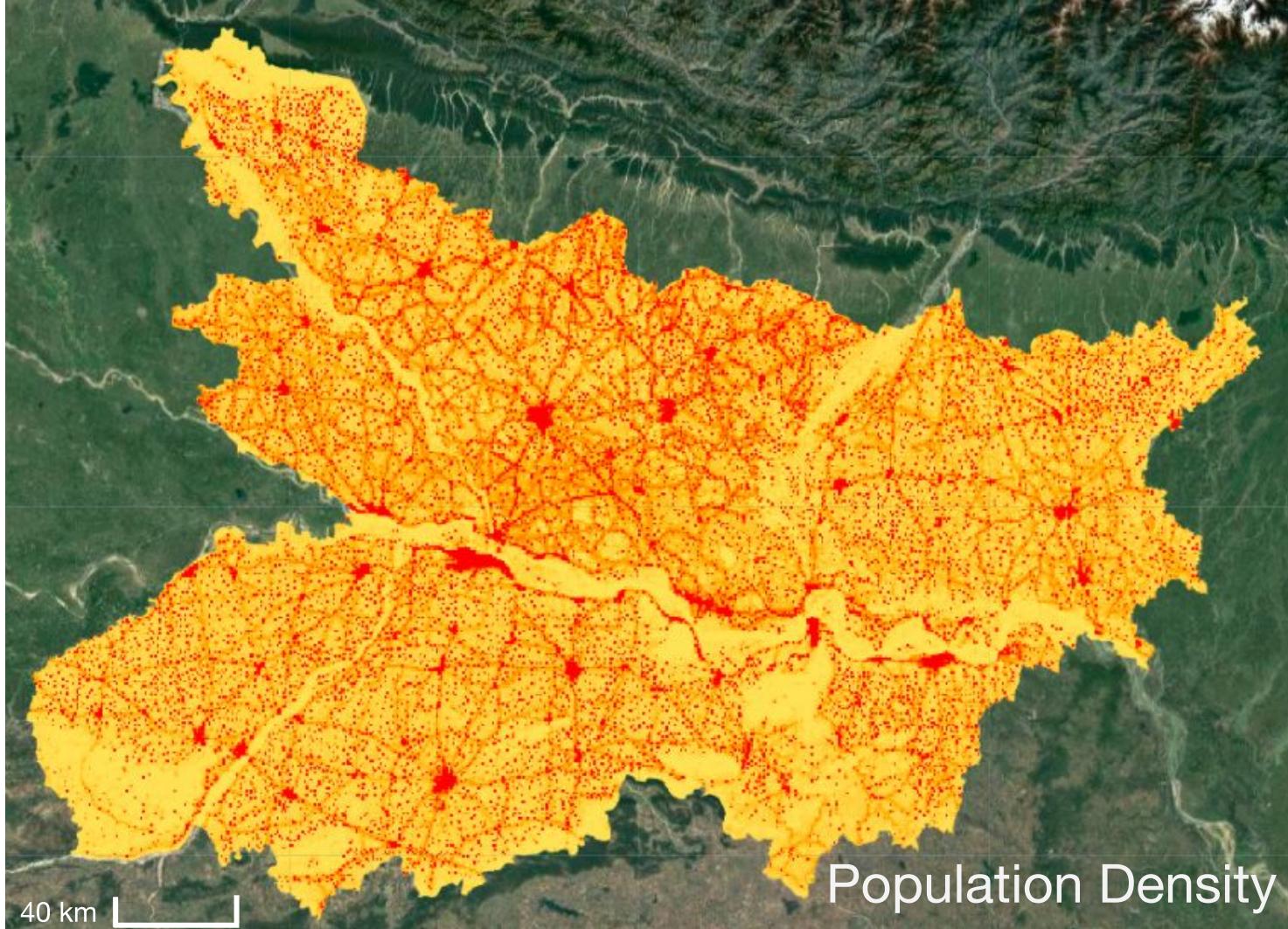


40 km

Spectral Imagery

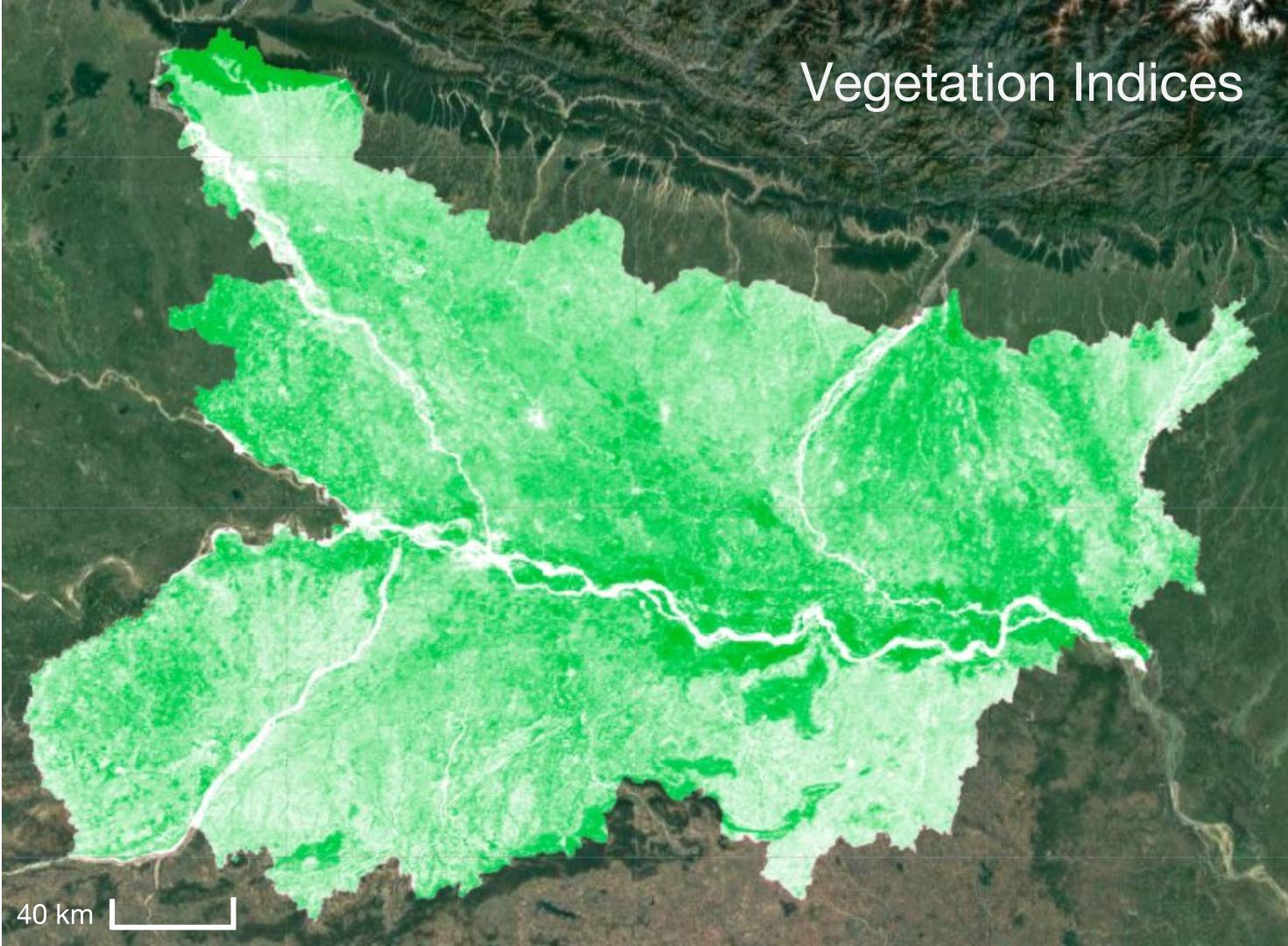
The Data

1



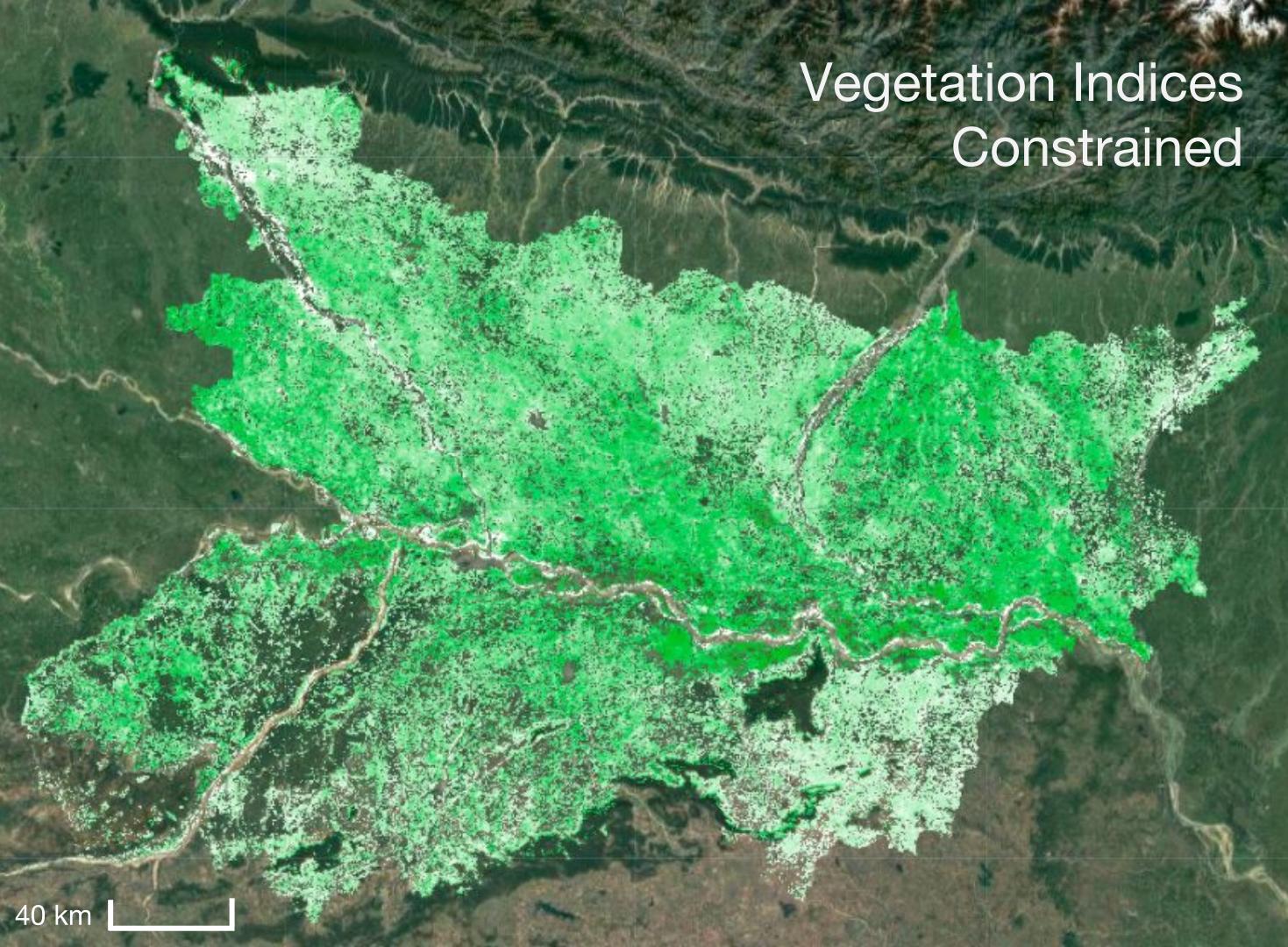
Targeted Data

Vegetation Indices

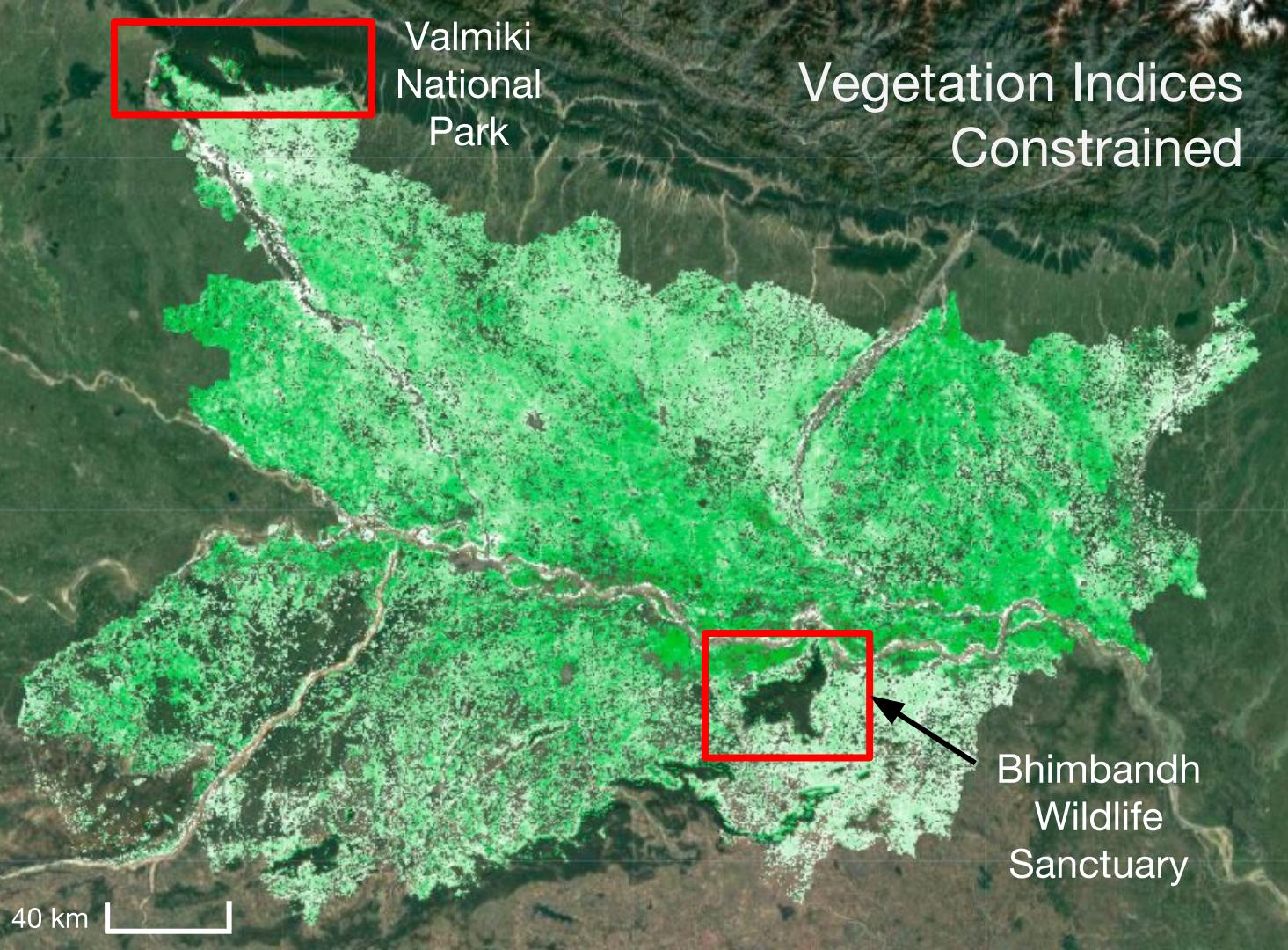


Targeted Data

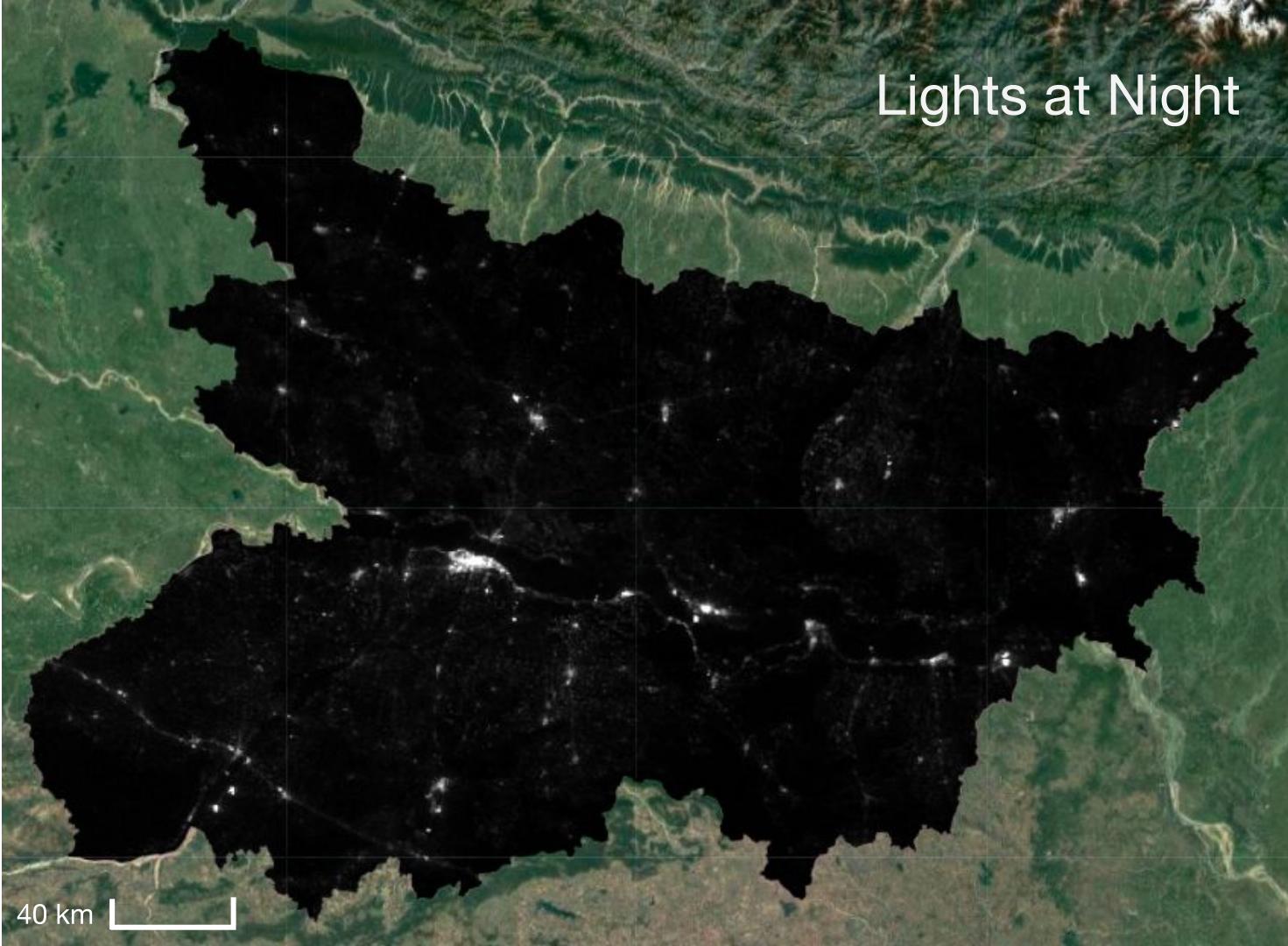
Vegetation Indices
Constrained



Targeted Data

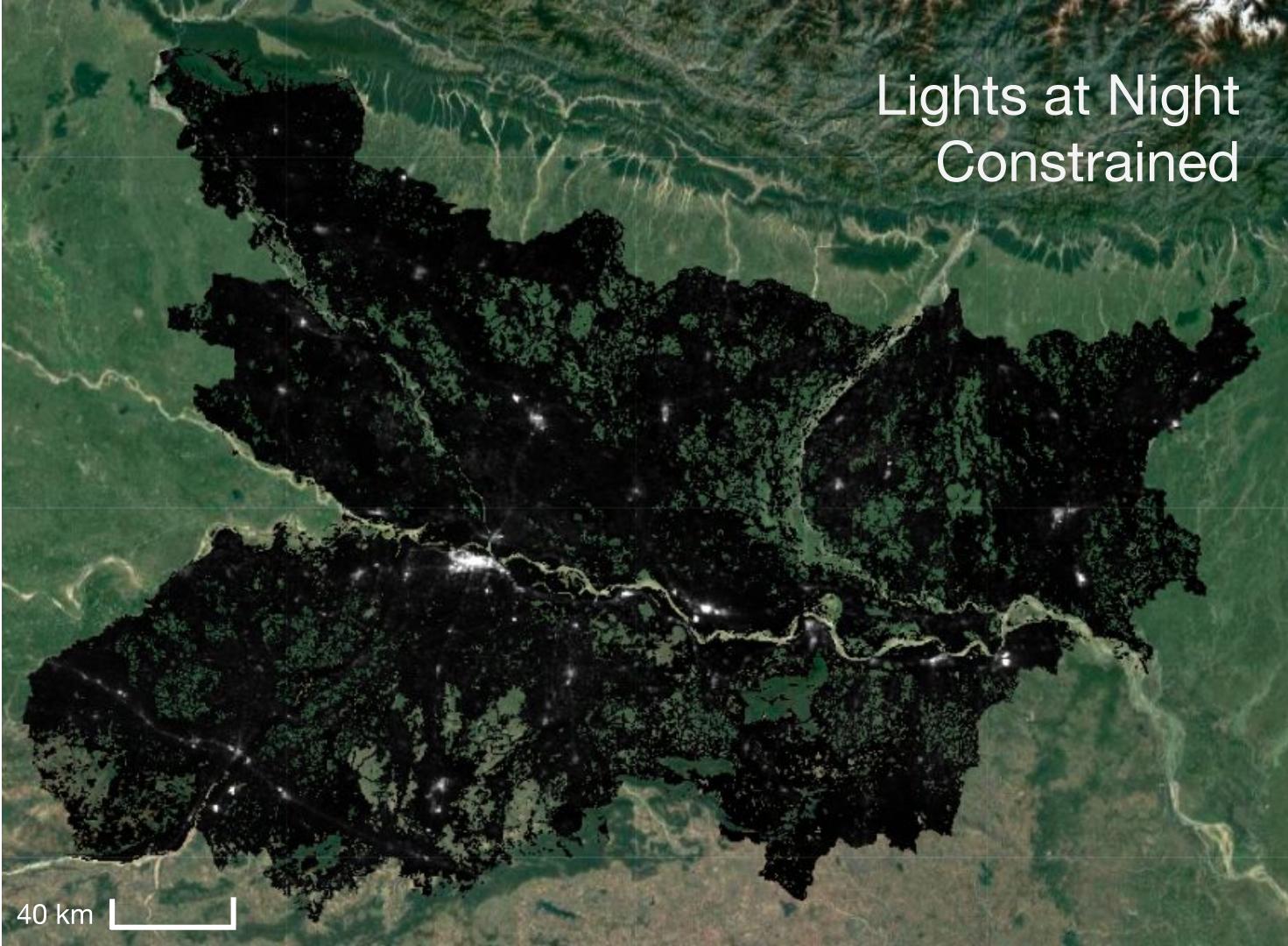


Targeted Data



Targeted Data

Lights at Night
Constrained



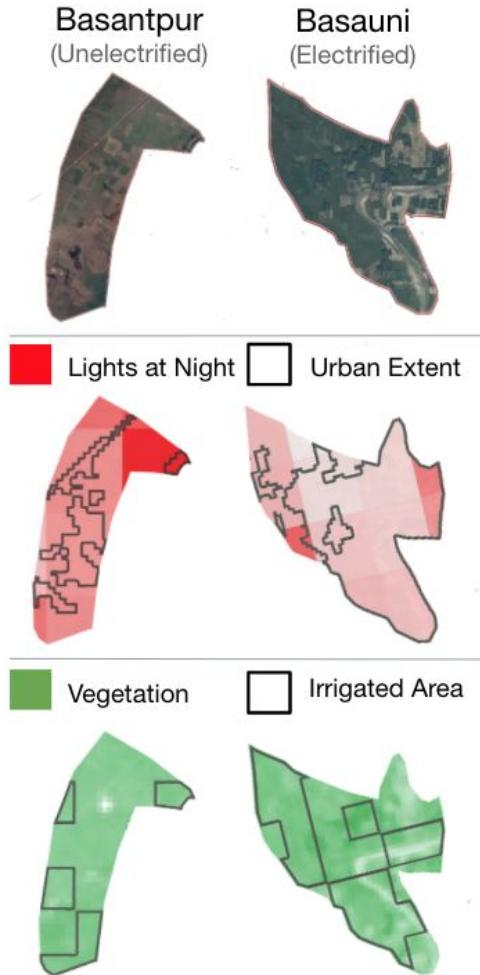


*villages not to scale

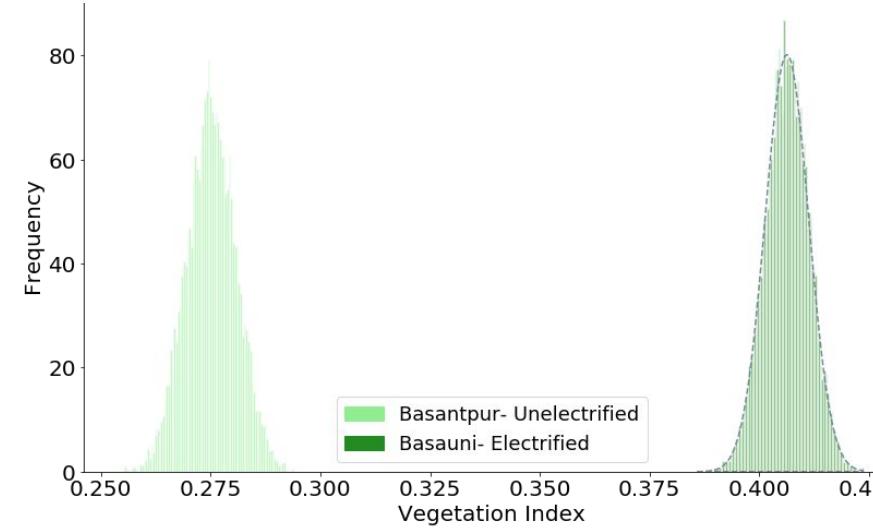
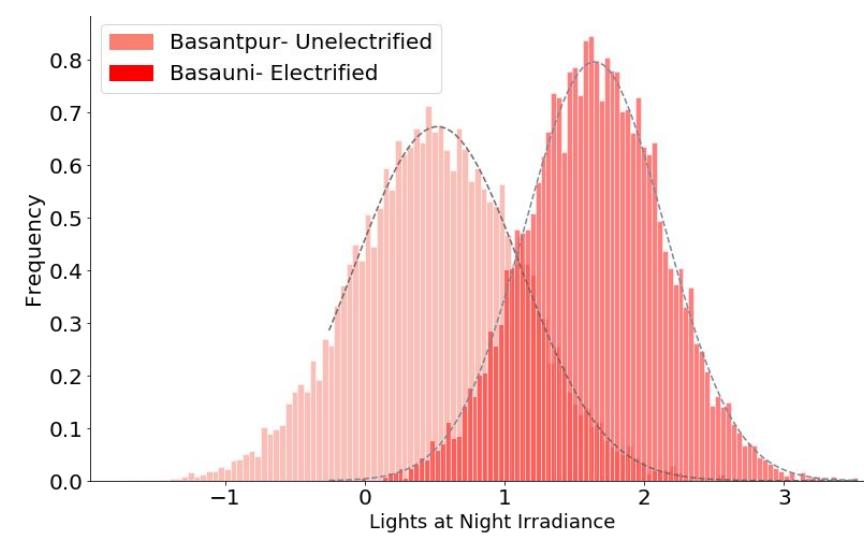
Feature Extraction

Extract 370 unique features from satellite imagery

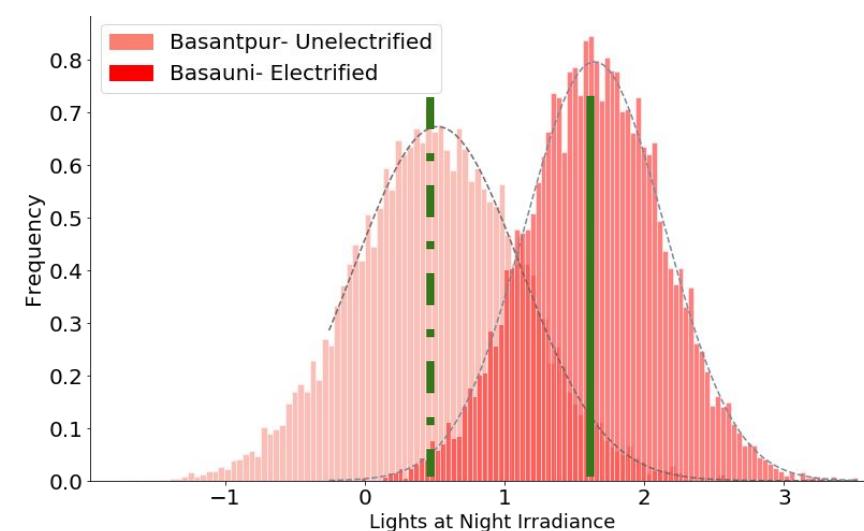
Train machine learning classifier on electrification status using extracted features



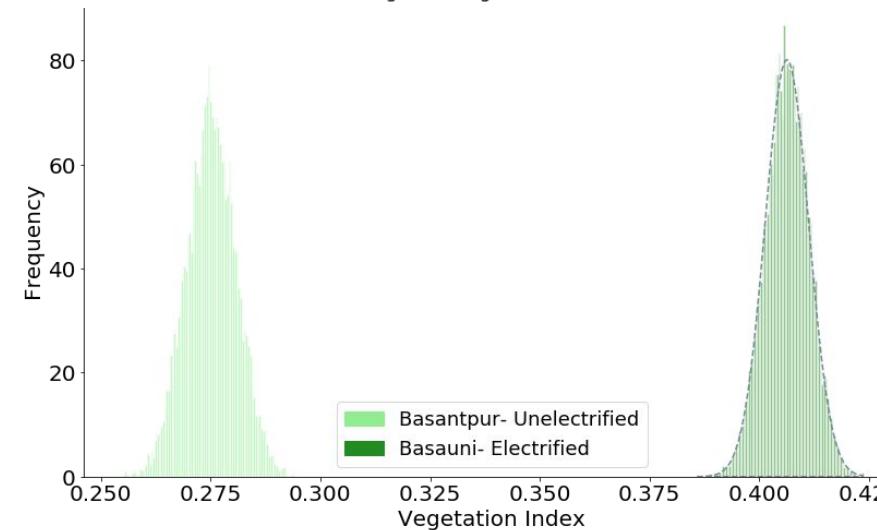
Feature Extraction



Feature Extraction

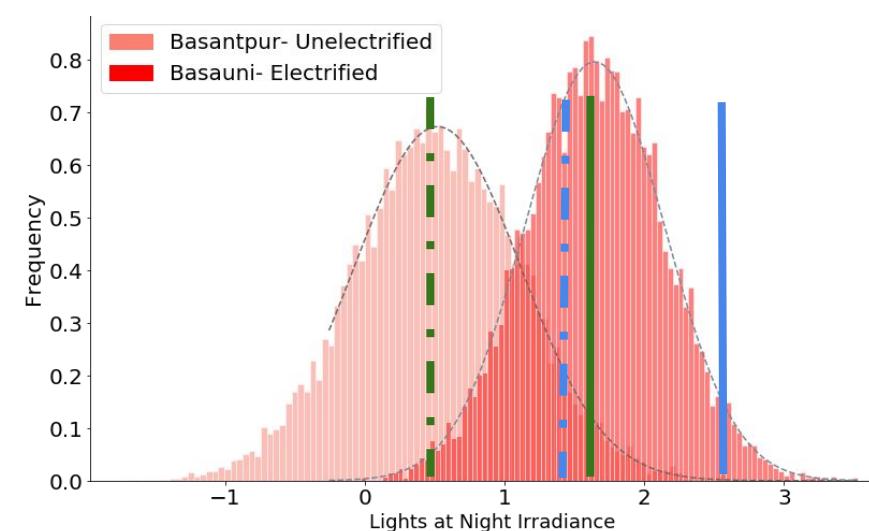


Lights at Night - Basauni
Median 1.78



Lights at Night - Basantpur
Median 0.50

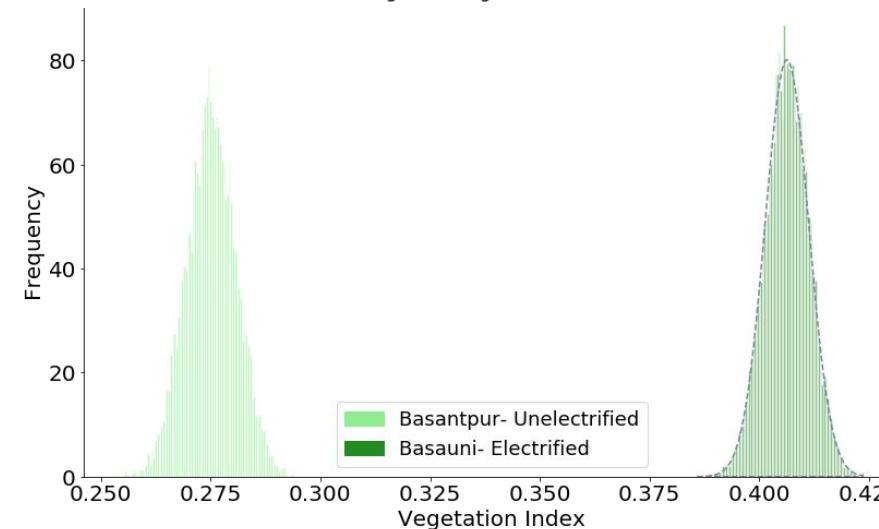
Feature Extraction



Lights at Night - Basauni

Median 1.78

90th percentile 2.60

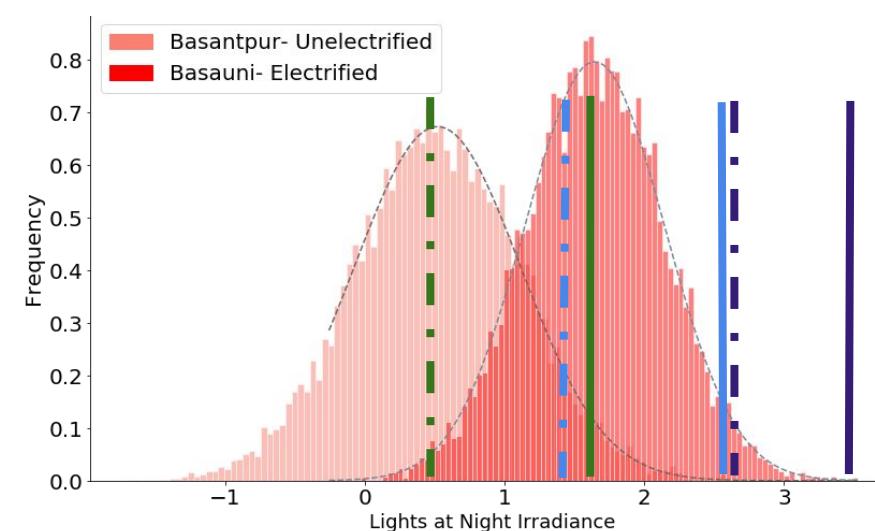


Lights at Night - Basantpur

Median 0.50

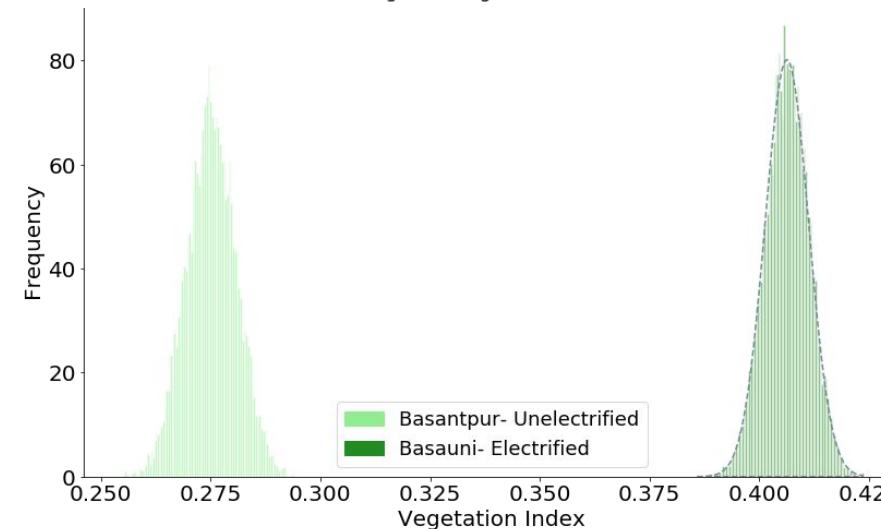
90th percentile 1.40

Feature Extraction



Lights at Night - Basauni

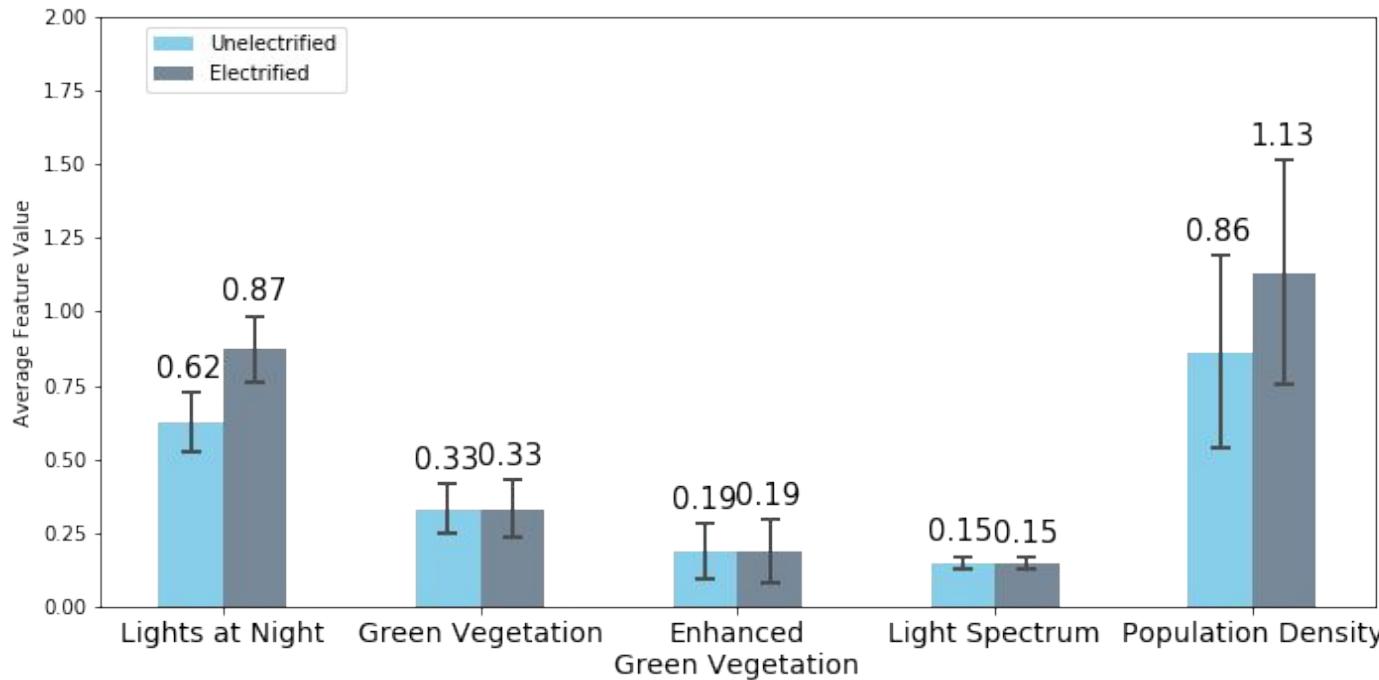
Statistic	Value
Median	1.78
90th percentile	2.60
Max	3.56



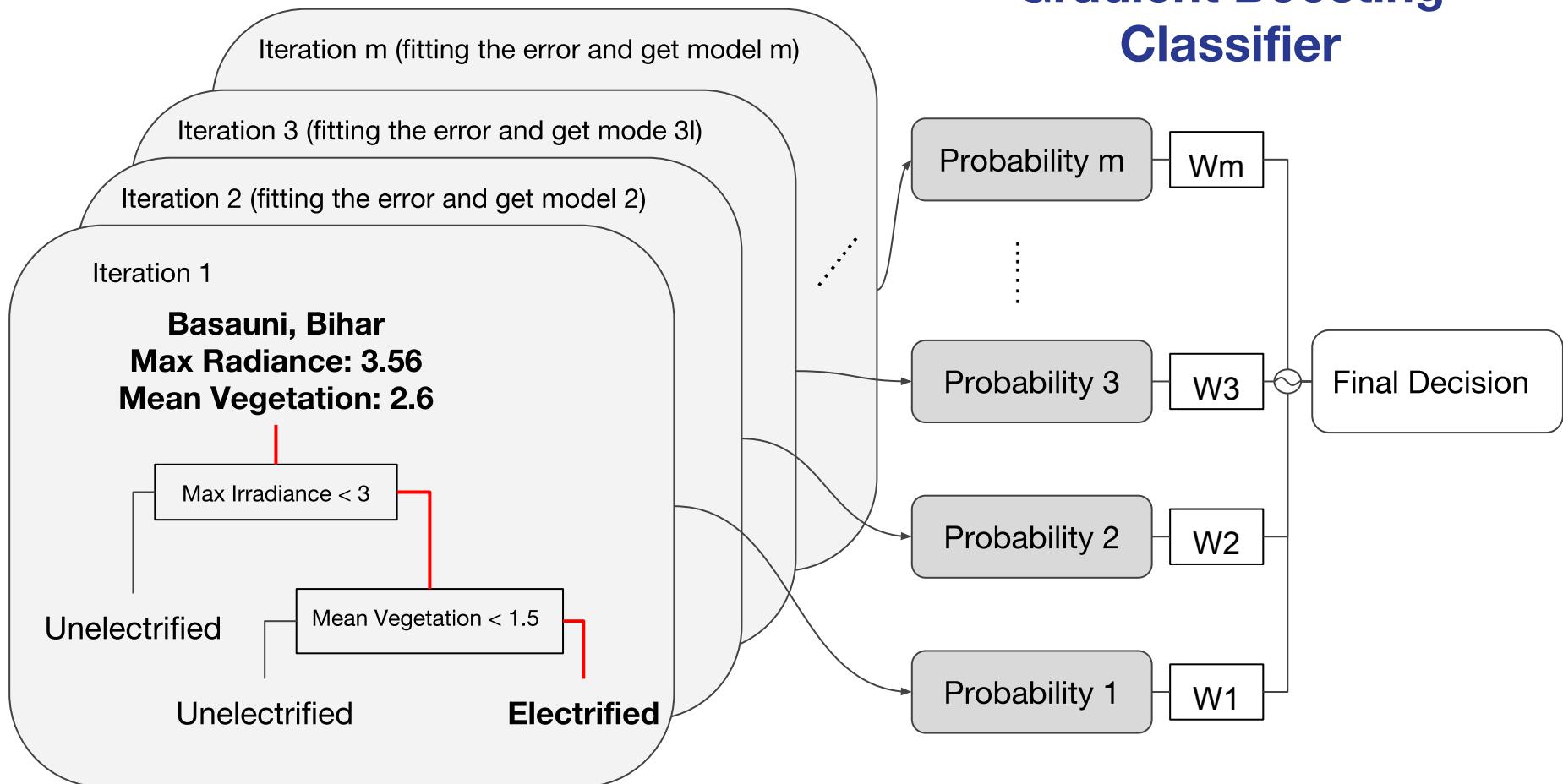
Lights at Night - Basantpur

Statistic	Value
Median	0.50
90th percentile	1.40
Max	2.70

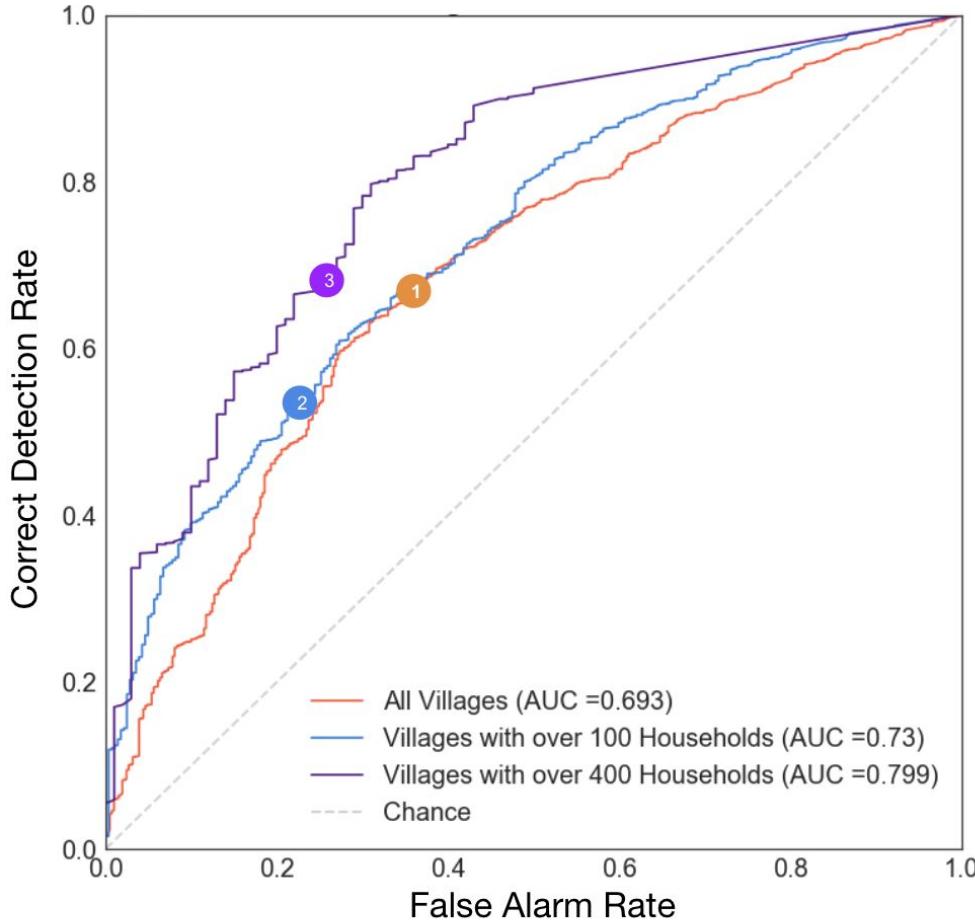
The Model → Gradient Boosting Classifier



Gradient Boosting Classifier



Model Result



Confusion Matrix of All Villages

		Prediction		Total
		Unelectrified	Electrified	
Truth	Unelectrified	64.1%	35.9%	[409]
	Electrified	33.2%	66.8%	[8654]

Villages with Over 100 Households

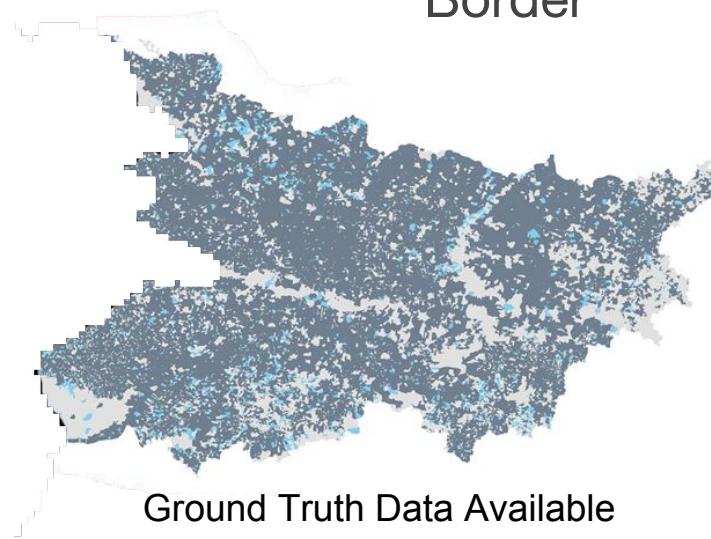
		Prediction		
		Unelectrified	Electrified	
Truth	Unelectrified	77.3%	22.7%	[282]
	Electrified	46.4%	53.6%	[4366]

Villages with Over 400 Households

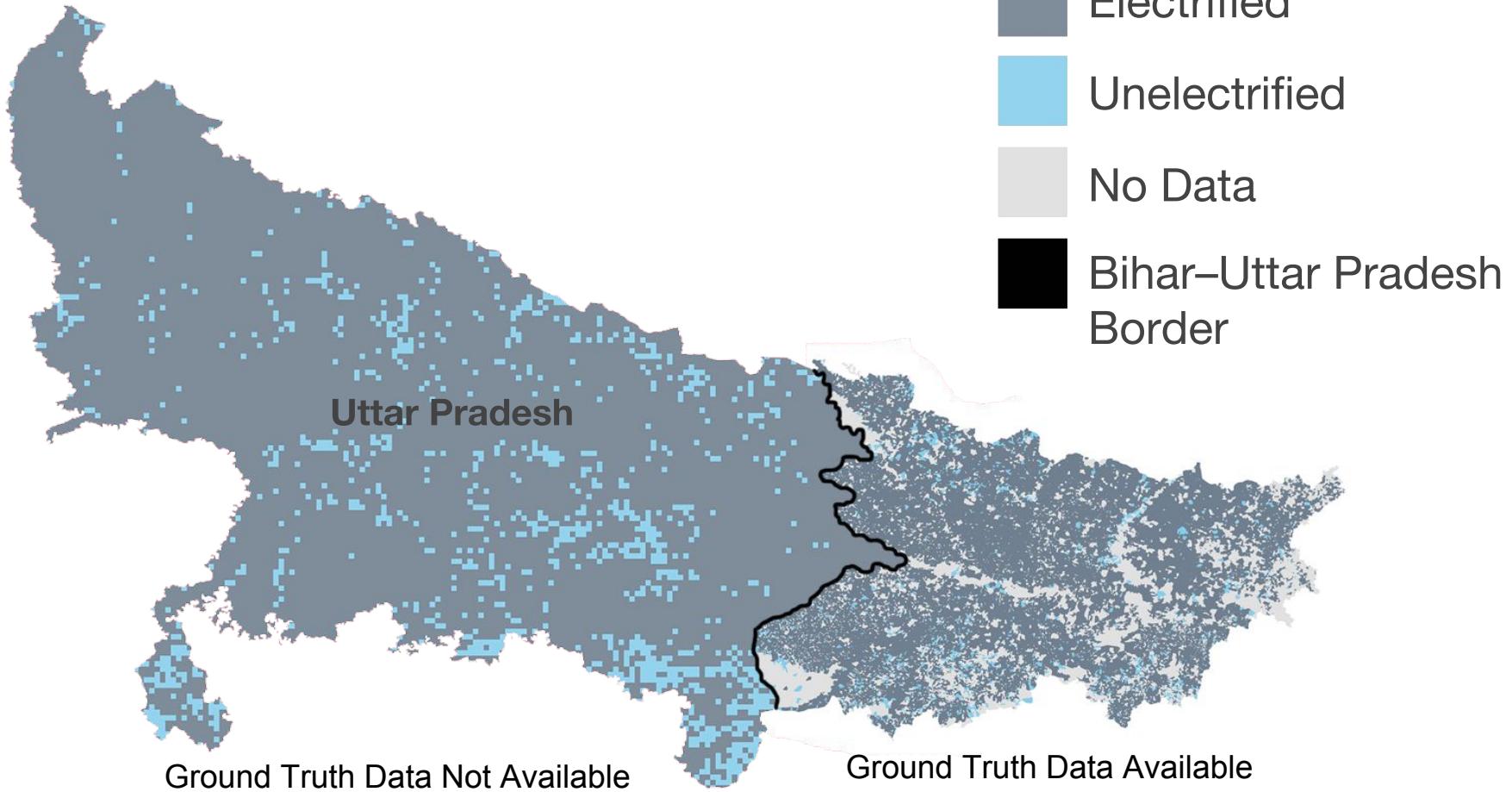
		Prediction		
		Unelectrified	Electrified	
Truth	Unelectrified	74.0%	26.0%	[100]
	Electrified	31.6%	68.4%	[1481]

Mapping Output

- Electrified
- Unelectrified
- No Data
- Bihar–Uttar Pradesh Border



Mapping Output

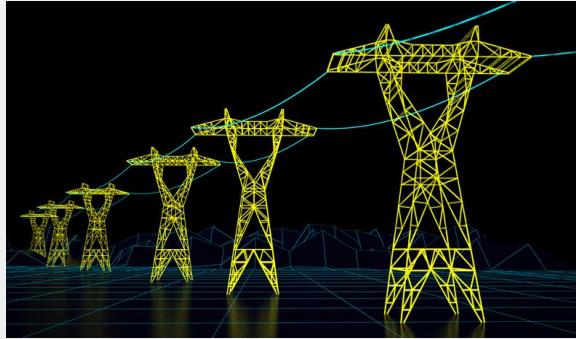


Pathways to Electrification



Sources: Off Grid Kindred, The Indian Express, Inhabitat

Pathways to Electrification

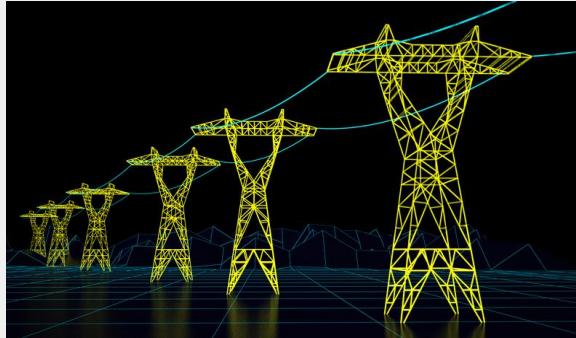


Grid Extensions



Sources: Off Grid Kindred, The Indian Express, Inhabitat

Pathways to Electrification



Grid Extensions



Microgrids



Sources: Off Grid Kindred, The Indian Express, Inhabitat

Pathways to Electrification



Grid Extensions



Microgrids



Off-Grid Access



Sources: Off Grid Kindred, The Indian Express, Inhabitat

Potential Future Applications



STAR

Study of the Tsunami Aftermath and Recovery

Potential Future Applications



STAR

Study of the Tsunami Aftermath and Recovery



Election cycles and electricity provision: Evidence from a quasi-experiment with Indian special elections

Thushyanthan Baskaran ^a, Brian Min ^b, Yogesh Uppal ^{c,*1}

Conclusions



Conclusions



Source: NASA

Acknowledgements

Thanks so much to our ever-supportive, incredibly kind, and patient faculty advisors who have been with us every step of the way on this tough problem:

Dr. Kyle Bradbury (Energy Initiative), Dr. Leslie Collins (Pratt), Dr. Timothy Johnson (Nicholas), Dr. T. Robert Fetter (Nicholas Institute), Dr. Marc Jeuland (Sanford)

Questions?



References

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6. Shi, K., Yu, B., Huang, Y., Hu, Y., Yin, B., Chen, Z., Wu, J. (2014). Evaluating the Ability of NPP-VIIRS Nighttime Light Data to Estimate the Gross Domestic Product and the Electric Power Consumption of China at Multiple Scales: A Comparison with DMSP-OLS Data. *Remote Sensing*, 6(2), 1705–1724.
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<http://www.thewatt.com/node/170>.